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Full-Scale Submarine Ventilation Doctrine and Tactics Tests

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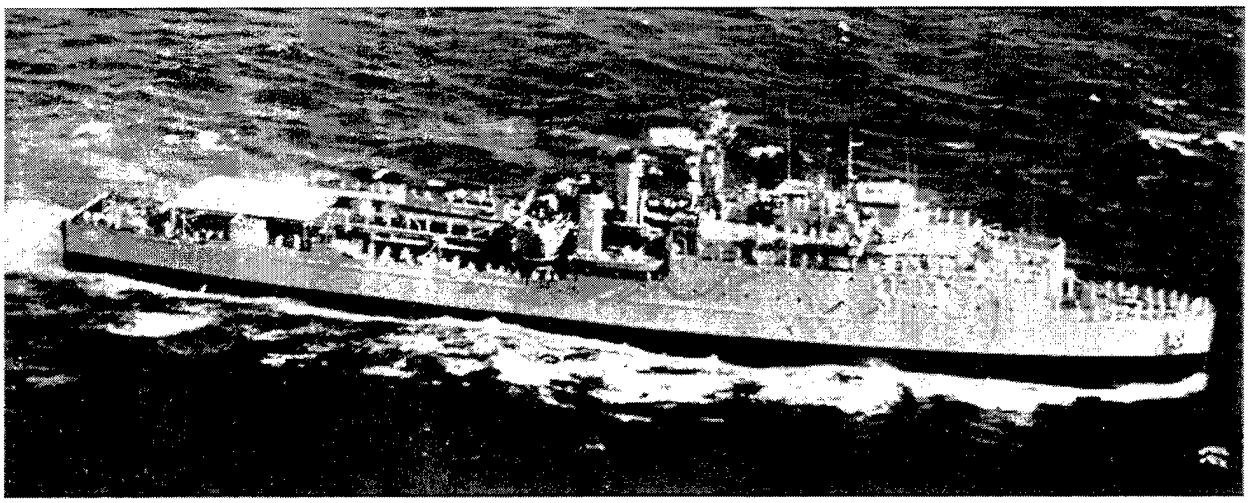

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13. ABSTRACT (*Maximum 200 words*)

A series of manual intervention fire fighting tests was conducted onboard the ex-USS SHADWELL, the Navy's full-scale damage control platform. The test series evaluated the fire fighters response to underway fire scenarios with respect to the overall tenability conditions (heat and smoke buildup) in the boat, particularly to the Control Room. The underway draft ventilation doctrine was also verified. The test program was intended to provide the technical and scientific basis for changes and improvements to the Naval Ships' Technical Manual (NSTM) 555, Volume 2. Tests were conducted in a simulated Auxiliary Machine Room (AMR) and Laundry compartment with Class A (ALPHA) and Class B (BRAVO) fire threats. The value of fresh water 1.9-cm (0.75-in.) hose reel systems for Class A fire fighting was demonstrated and verified, along with the importance of quick response to fires and personal protection. The use of various ventilation alignments to improve tenability conditions throughout the boat was demonstrated to the Fleet personnel during the fire tests. The detailed results of the tests provide the basis for improved submarine fire fighting doctrine and tactics. Recommendations are also included for improved equipment design.

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EXECUTIVE SUMMARY

A series of seven manned intervention tests utilizing Fleet personnel were conducted during the week of 16-19 June 1997 onboard the ex-USS SHADWELL, the Navy's full-scale damage control R&D platform. All testing was conducted in the port wing-wall of the SHADWELL which has been modified to simulate the forward compartment of a 688 Class submarine. The full-scale submarine ventilation doctrine fire testing was conducted as part of the Submarine Fire Safety Improvement Program. This test program was intended to provide the technical and scientific basis for changes and improvements to the Naval Ships' Technical Manual (NSTM) 555, Volume 2. The objective of this series was to evaluate the response of the fire fighters to various underway fire scenarios with respect to the overall tenability conditions, particularly in the Control Room. The effect of various ventilation alignments to improve fire fighting conditions and Control Room tenability was also evaluated. Auxiliary Machine Room (AMR) and Laundry fire scenarios were used in the manned fire fighting tests to investigate improvements to doctrine, tactics, procedures and equipment. The use of portable extinguishers, hose reels and hand lines, combined with ventilation doctrine, was assessed in terms of Control Room tenability as well as fire suppression effectiveness.

Class A (ALPHA) wood cribs and Class B (BRAVO) diesel pan fires were used in this test series. In all tests, the submarine was assumed to be underway at the time of the fire. In the initial tests the fires were easily accessible to the fire fighters. As the testing progressed, the fires became harder to access and more difficult to extinguish. The fires also became larger and more complex requiring multiple hand lines and multi-deck fire fighting.

The test series followed current response procedures aboard submarines when a fire occurs. Standard response procedures were followed for the Watchstander discovering the fire, the Rapid Response Team, hose teams and the Man-in-Charge. Standard personnel protection equipment for submarine fire fighters was used. One exception was test personnel wore OBAs fitted with a rope tethers to simulate EAB masks. The Control Room was manned and standard announcements were made over the general announcing system. Portable radios were used to simulate sound-powered phones.

The first three tests involved Class A fires and were conducted to provide a baseline of current fire fighting practice. As such, ventilation was secured when the fire was reported and remained secured until the fire was out. It was assumed that the fire was reported while the submarine was submerged. These tests investigated post-fire desmoking techniques, conducted at periscope depth, including the standard Emergency Ventilation alignment exhausting with the L.P. blower. Emergency exhaust was through the ventilation terminal located in the NAV Equipment Room. These ventilation alignments provided minimal improvement in the Control Room tenability and little improvement in the lower levels of the test space.

As testing progressed, fire fighters experimented with varying fire attack techniques, active desmoking (using ventilation before the fire is out), and modified post-fire desmoking techniques. During the last four tests, it was assumed that the fire was reported while the submarine was operating at periscope depth. After an appropriate time delay, representing the time to surface, active desmoking and post-fire desmoking techniques (that could be used on the surface) were evaluated.

The significant findings from the test series are summarized below; they are discussed in more detail in the enclosed report.

SHADWELL/688. Fleet and training command personnel concluded that the SHADWELL/688 provided for credible evaluations of submarine fire fighting doctrine. In addition, the SHADWELL/688 provided a unique experience for the Navy's submarine fire fighting training personnel to substantially improve their fire fighting knowledge and their abilities to train Navy personnel in submarine fire fighting.

Fire Fighting Organization. The fire fighting organization currently used aboard submarines today is basically sound. The tests identified refinements in that organization that would improve the fire fighting response aboard submarines.

NSTM 555. Changes to NSTM 555 Vol. 2 should be made to incorporate the applicable findings of these tests so NSTM 555 more accurately describes the fire fighting response aboard submarines. Since NSTM 555 is the basis of fire fighting training, these changes will improve future submarine fire fighting training.

Single Hose. Only a single hose should be used to attack the large majority of fires that occur aboard submarines. Attacking with more than one hose actually impedes effective fire fighting in most situations.

Active Desmoking. The Control Room Sweep (bridge hatch open and L.P. blower exhausting from NAV Equipment Room) was very effective at quickly reducing the heat and smoke buildup in the Control Room.

Visibility. Chem Lites on equipment and personnel made it significantly easier to find them in smoke. Chem Lites should be pre-staged on EAB manifolds.

Portable Extinguishers. Appropriate portable extinguishers should be brought to the scene by the Watchstander and the Rapid Response Team. A PKP extinguisher was shown to be very effective for the initial knock-down of Class A and Class B fires. Since PKP does not cool the fuel, it needs to be followed up quickly with water or AFFF as appropriate. CO_2 is effective against Class C and small Class A fires that are not deep-seated; it is the appropriate agent for the large majority of fires aboard a submarine and should be used for the initial response unless conditions indicate otherwise.

Hose Technique. Hose stream techniques are more important than water volume for effective fire fighting. The appropriate low water use hose stream techniques, such as short bursts to cool hot gases for different fire conditions, should be emphasized in fire fighting training.

Hose Reel. The 1.9-cm (0.75-in.) hose reel is very effective; it is faster and requires less manpower than a 3.8-cm (1-½ in.) hose.

Test personnel reported that operating the supply and induction fans in conjunction with the Control Room Sweep improved conditions in the Control Room and on lower platforms during active and post-fire desmoking. This technique should be evaluated further as a potential, additional improvements in the doctrine.

Fleet personnel were used as expert fire fighters during the test series. Personnel from the following activities participated in the tests: Fire Fighting School and Submarine Training Facility (SUBTRAFAC), Norfolk, Virginia; Trident Training Facility (TRITRAFAC), Kingsbay, Georgia; Submarine Force, U.S. Atlantic Fleet (COMSUBLANT); USS NORFOLK; and Naval Safety Center (NAVSAFCEN), Norfolk, Virginia. The knowledge and enthusiasm of these personnel made a major contribution to the success of the testing.

FULL-SCALE SUBMARINE VENTILATION DOCTRINE AND TACTICS TESTS

1.0 INTRODUCTION

This report describes the testing conducted onboard the ex-USS SHADWELL, the Navy's full-scale damage control R&D platform [1]. The subject tests represent Phase II of a two-part test program designed to investigate the ventilation effects of an underway Auxiliary Machine Room (AMR) fire scenario. The new draft ventilation doctrine [2] for underway fire scenarios was also evaluated during Phase II testing. This test program was intended to provide the technical and scientific basis for changes and improvements to the Naval Ships' Technical Manual (NSTM) 555, Volume 2 [3]. The full-scale submarine ventilation doctrine fire testing, was conducted as part of the Submarine Fire Safety Improvement Program. Phase I testing [4] involved modifications to the SHADWELL/688 test area, in order to create the necessary configuration and ventilation conditions necessary for AMR testing. The results of Phase I testing [4] and previous test programs [5-9] were incorporated into the Phase II manual intervention test program. The goal of Phase II testing was to evaluate fire fighters' response to various underway fire scenarios with respect to tenability conditions, particularly in the Control Room. The effect of various ventilation alignments to improve fire fighting conditions on lower platforms was also evaluated.

2.0 BACKGROUND

Full-scale manned submarine ventilation doctrine fire testing, associated with the Submarine Fire Safety Improvement Program, was conducted during the time period of 16-20 June 1997. This was the eighth series of tests performed in conjunction with this program. The tests involved the investigation of the effects of ventilation, configuration, manual intervention, fire fighting equipment and tactics/procedures for combating fires on 688 Class submarines. All testing was conducted in the SHADWELL/688 test area, constructed within the Naval Research Laboratory's full-scale fire research platform, the ex-USS SHADWELL, located in Mobile, Alabama [1].

Initial submarine testing [5-9] involved the examination of the fire physics to better understand how fires behave in a submarine. Two recent test series [8,9] developed in-port and at-sea ventilation doctrine in the event of a fire. The tests focused on the results of various ventilation alignments for fires in the forward compartment, particularly for fires forward of the

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Auxiliary Machine Room (AMR) on the second and third platforms. A fire in the AMR was not specifically considered previously.

To evaluate AMR ventilation doctrine and identify potential improvements in manual fire fighting equipment, tactics and procedures, a two phase test program was planned. In Phase I [4], various ventilation condition scenarios were developed and evaluated for underway conditions (submerged, periscope depth and surfaced). Tenability conditions in other spaces of the forward compartment, particularly the Control Room, were compared to previous test results [8,9]. Fire scenarios involving Class A and three-dimensional Class B (fuel spray fires) threats were developed and evaluated.

Results of Phase I testing demonstrated limited effectiveness in improving tenability conditions throughout the boat, and particularly in the Control Room, when emergency ventilation commenced at periscope depth. Emergency ventilation involved drawing fresh air in from weather through the induction mast and exhausting heat and smoke to weather (or ballast tanks on an actual submarine) using the L.P. blower from either the third platform (AMR) or the first platform (NAV Equipment Room) exhaust terminal.

Previous tests demonstrated the difficulty in maintaining tenability in the forward compartment during a fire. Consequently, efforts for at-sea doctrine focused on maintaining tenability in the Control Room for two reasons. First, the Control Room is essential to the safe operation of the submarine. Second, heat and smoke accumulate in the Control Room from fires in the forward compartment, rapidly reducing tenability conditions. The testing also demonstrated minimal improvement in Control Room tenability while the submarine was submerged.

Of the various ventilation alignments tested, the most effective method of improving tenability in the Control Room involved opening the bridge hatch, opening the NAV Equipment Room door, the Fan Room door and exhausting heat and smoke through the L.P. blower exhaust terminal in the NAV Equipment Room. This "Control Room Sweep" established a flow of fresh air from the bridge hatch, through the Control Room and out the emergency exhaust terminal. This sweep procedure was supplemented in later tests by concurrent operation of the supply fan.

The Phase II manned test series was used to investigate the use of post-fire desmoking techniques while at periscope depth and the use of the Control Room Sweep for active desmoking (desmoking before the fire is out) when surfaced. Since this was the first manned test series aboard the SHADWELL/688, the test series also evaluated current, standard submarine fire fighting practices to establish a performance baseline and to identify potential improvements. The test plan for these Phase II tests was approved and published [10]. This report summarizes the results of the Phase II manned fire fighting ventilation doctrine tests.

3.0 DRAFT DOCTRINE

A new submarine ventilation doctrine for the forward compartment of a 688 Class submarine has recently been developed [2]. The doctrine provides effective ventilation techniques which include:

1. For pier-side fires in the forward compartments, use of hatch openings to allow for the natural ventilation of smoke and heat from the submarine out the bridge hatch or weapons loading hatch while providing a clean re-entry and muster environment on the mess deck for fire fighting personnel entering through the forward escape trunk;

2. For fires at sea, use of the Control Room Sweep as described in Section 2. Background.

Testing to develop and validate the draft submarine ventilation doctrine has been ongoing for the past several years. A series of seven unmanned full-scale submarine venting doctrine fire tests, associated with the Submarine Fire Safety Program, has been conducted. These tests focused on Class A and B fires. Various effective ventilation schemes were developed to maintain tenable conditions in the Control Room in terms of heat and smoke accumulation for underway scenarios. Ventilation schemes were also developed to provide tenable conditions in the mess deck area to allow for egress of personnel and re-entry for fire fighting teams while pier-side.

In order to evaluate the effect of active fire fighting on tenability conditions in the Control Room, a manned intervention fire test series was planned. The testing evaluated ventilation doctrine and identified improvements in manual fire fighting equipment, tactics and procedures. The effect of manual intervention on fire growth and suppression was evaluated for underway scenarios only. Effectiveness of the fire fighting activities was evaluated in terms of tenability conditions (heat and smoke buildup) in the Control Room.

To properly implement the new doctrine, it had to be evaluated under controlled realistic fire scenarios with submariners trained in the principles of submarine fire fighting tactics and procedures. The ventilation doctrine will be included in instructors manuals, training curricula, ships technical manuals and damage control books. It was the intent of this test series to obtain the necessary data and Fleet feedback from actual fires in a simulated submarine environment. These inputs, along with fire fighting experience, would improve the doctrine and tactics and be incorporated into existing practice.

4.0 OBJECTIVES

The objective of the manned intervention test series was to evaluate the effectiveness of fire fighting techniques, equipment and procedures against modest Class A and B fire threats in terms of Control Room tenability. Variables in this test series included fire size and location, type of fire fighting equipment used and ventilation actions. The testing evaluated several submarine underway conditions (submerged, periscope depth and surfaced). Specific objectives of the test series were to:

1. Evaluate various underway emergency ventilation techniques (i.e., current doctrine techniques and new techniques developed from unmanned testing);

2. Evaluate fire fighting techniques in realistic Class A and B fire scenarios with respect to maintaining Control Room tenability conditions;

3. Demonstrate the use of the 1.9-cm (0.75-in.) hose reels to Fleet personnel and obtain user feedback;

4. Provide an opportunity for Fleet submariners to work with new equipment and ventilation techniques and to comment on the proposed changes to current doctrine and tactics; and

5. Validate the findings from previous unmanned fire tests under realistic fire conditions.

5.0 APPROACH

To meet these objectives, the results of the Phase I testing were analyzed and a test plan incorporating manual intervention was developed. The Phase I testing focused on the ventilation effects on overall tenability conditions, particularly in the Control Room, for various fire scenarios and underway conditions. Phase II testing focused on the response of the fire fighters in controlling and extinguishing the fire and the effect of various ventilation effects in reducing the heat and smoke impact on fire fighters to improve the fire fighting conditions and tenability conditions in the Control Room.

The key requirement in developing the test plan was the development of repeatable fire scenarios. The fire scenarios had to be challenging to the equipment and personnel being tested yet realistic within the context of a submarine environment. The actual mock-up of the forward compartment of a Class 688 submarine with installed materials was necessary only to the extent of simulating key elements effecting fire fighting. The following important elements were incorporated for these tests:

1. Fire growth was controlled so that the stage of the fire relative to the initiation of fire attack was known and repeatable;

2. The space(s) containing the fire(s) was small and very congested with obstructed access;

3. The approach to the fire area was through very narrow passageways;

4. Ladders and scuttles were present to represent access to the fire area from above or below deck; and

5. Retention of heat and smoke was representative of the enclosed submarine environment.

To evaluate the effectiveness of fire fighting equipment, tactics and procedures, a series of seven tests were planned involving Class A and B fires, located in various locations throughout the lower platform of the SHADWELL/688 test area. Initial fires were relatively easy to access and extinguish. The access to subsequent fires was increasingly more difficult with various obstructions placed near the fire location to delay fire fighting efforts. Initial ventilation conditions utilized were applied from the current fire fighting doctrine. Subsequently, new ventilation techniques were tested to evaluate Control Room tenability conditions and acquire fleet personnel feedback.

6.0 TEST FACILITY AND PERSONNEL

The SHADWELL/688 test area layout, showing compartment designations and orientations, is shown in Figure 1. Figure 2 shows doorway and hatch designations and locations. Class A and B fire tests were conducted in the Auxiliary Machine Room (AMR) and the Laundry space. Metal storage cabinets, approximately 1.5-m (5-ft) high were placed in the Laundry to obstruct access to or conceal the source of the fire. Large metal obstructions were placed in the AMR to simulate the diesel generator, scrubbers, generators and hydraulic machinery and restrict the movements of the fire fighters.

Enlisted personnel were used as expert fire fighters during the test series. Personnel from the following activities participated in the tests: Fire Fighting School and Submarine Training Facility (SUBTRAFAC), Norfolk, Virginia; Trident Training Facility (TRITRAFAC), Kingsbay, Georgia; Submarine Force, U.S. Atlantic Fleet (COMSUBLANT); USS NORFOLK; and Naval Safety Center (NAVSAFCEN), Norfolk, Virginia.

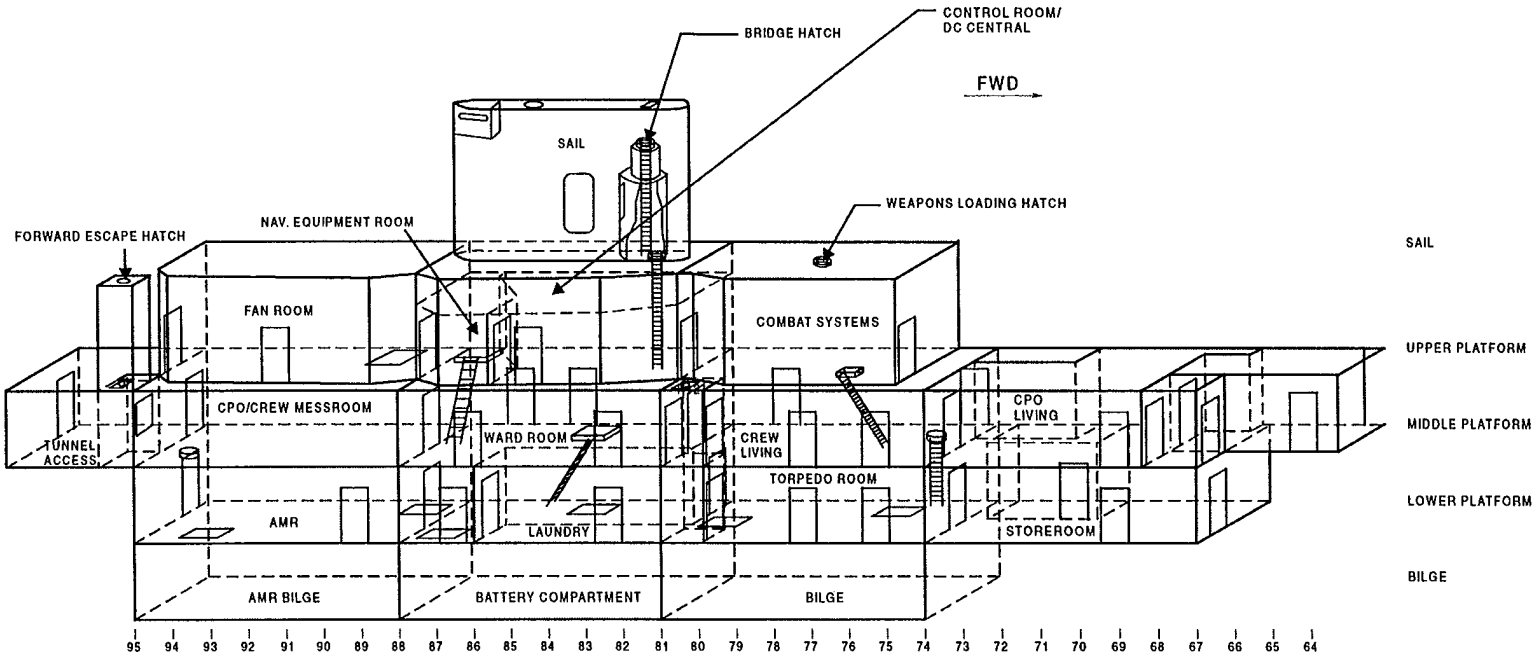


Fig. 1 — SHADWELL/688 test area

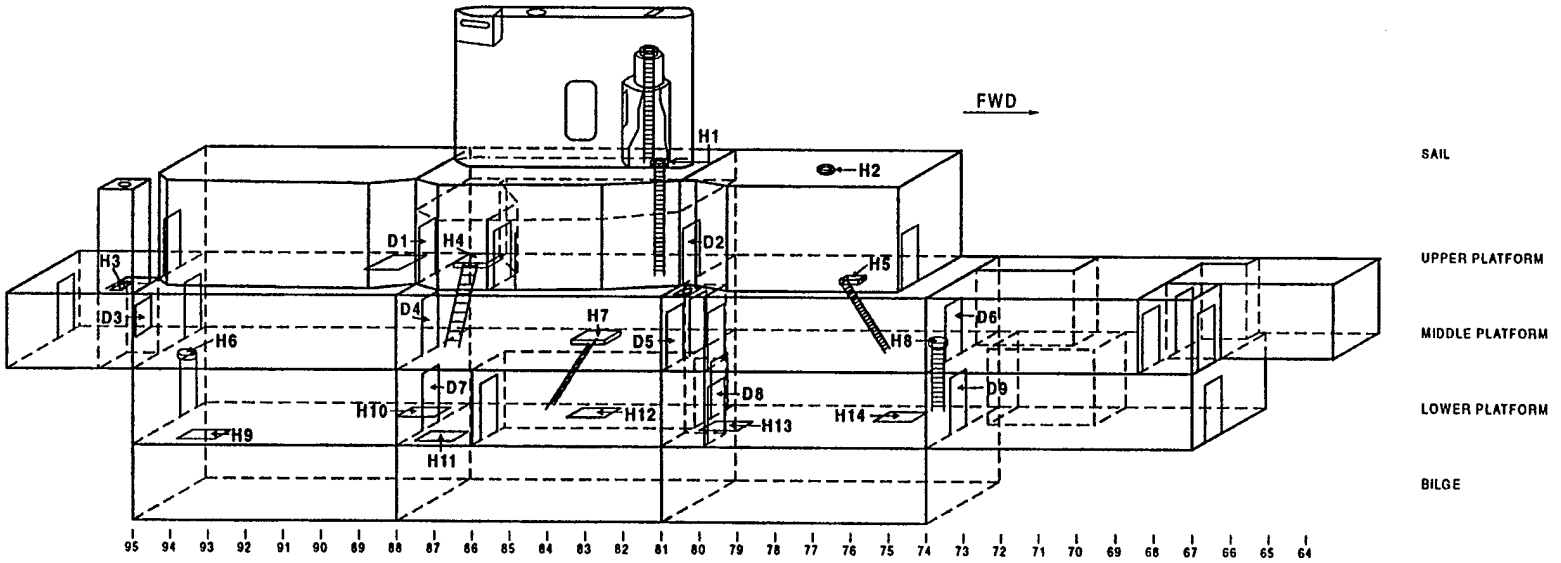


Fig. 2 — SHADWELL/688 Doorway and Hatch designations

7.0 EQUIPMENT

Test equipment pre-staged in the SHADWELL/688 test area included fire fighting equipment and protective equipment. All equipment used in the test program was identical to equipment currently being used onboard submarines. Method of stowage was repeated as nearly identical as possible to provide a realistic test scenario.

7.1 Fire Fighting Equipment

The following fire fighting equipment was used:

1. One 15.2 m (50 ft) length of 3.8-cm (1.5-in.) diameter double jacketed fire hose with a Type I, 3.8-cm (1.5-in.) 360 ℓpm (95 gpm) vari-nozzle MIL-N-24408 (Elkhart SFL-GN), preconnected and stored on camelback hose racks, with a nominal operating pressure of 5.5 barg (80 psig) and 322 ℓpm (85 gpm) flow;

2. Hose reels with roller guides in accordance with MIL-R-244414B Type III including:

   a. One 15.2 m (50 ft) length of 1.9-cm (0.75-in.) diameter hard rubber noncollapsable hose MIL-H-24580;

   b. A Type III 1.9-cm (0.75-in.) vari-nozzle MIL-N-24408 (Akron Model 4508);

   Operating pressure was nominally 5.5 barg (80 psig), with a nominal flow rate of 322 ℓpm (85 gpm);

3. 9.5 ℓ (2.5 gal) AFFF portable extinguishers in accordance with MIL-E-24652;

4. CO_2 extinguishers in accordance with MIL-E-24269;

5. PKP extinguishers in accordance with MIL-E-24091; and

6. Navy Fire Fighting Thermal Imager (NFTI), English Electric Valve, Model P224428-USN, NSN 4210-01-213-7310.

7.2 Protective Equipment and Clothing

Standard Navy clothing and protective clothing was used including:

1. FBM long-sleeved and short-sleeved submarine coveralls ("poopie suits") and high-top shoes;

2. Flashoods;

3. Cotton flash gloves;

4. Navy one-piece Nomex fire fighting ensemble;

5. Type 4A Oxygen Breathing Apparatus (OBA), NSN 4240006162857 with Draeger masks; and

6. Mine Safety Appliances Co. (MSA) Self Contained Breathing Apparatus (SCBA) simulating Emergency Air Breathing (EAB) masks.

The use of Emergency Air Breathing (EAB) apparatus is an integral part of submarine damage control doctrine. Piped, low pressure breathing air was not available for these tests. To simulate the use of an EAB, both SCBA's and OBA's were used to simulate EAB's. To simulate the breathing hose connecting the EAB mask to the EAB manifold and the restricted movement of the EAB wearer, an 2.44-m (8-ft) long piece of 0.6-cm (0.25-in.) diameter nylon rope with clips on both ends was used. The entire length of rope was wrapped with duct tape to make the rope less flexible to simulate the stiffness of the rubber hose. The two EAB masks with the 7.62-m (25-ft) long rubber hoses were also made available for use by the test personnel. Figure 3 shows the simulated EAB by the OBA and rope tether.

Due to supply system delays, none of the three authentic MIL-SPEC 1.9-cm (0.75-in.) hose reels were delivered in time for testing. As a substitute, two hose reels from fixed CO_2 extinguishing systems were installed with the MIL-SPEC 1.9-cm (0.75-in.) hose and nozzles. Additionally, only 1 Amerex 250N AFFF portable extinguisher was available. Amerex 250 9.5 ℓ (2.5 gal) portable water extinguishers were fitted with the air aspirating nozzle and filled with the correct AFFF/water mixture.

8.0 INSTRUMENTATION

Instrumentation was installed to measure the compartment temperatures, pressure, smoke density, gas flow, fuel mass loss and gas concentrations (CO, CO_2 and O_2). Ultrasonic flow meters and pressure gauges were used to measure handline flows and pressure. Ambient conditions, including barometric pressure, relative humidity, outside air temperature and wind speed and direction were monitored during each test. Test instrumentation was installed as described in the baseline test plan [11] and as modified in Phase I testing [4]. Data were collected by a MassComp data acquisition system located in the SHADWELL Test Control Room at a rate of 1 scan per second. Appendix A provides complete instrumentation drawings for each compartment. Appendix B provides the instrumentation in tabular form, giving the ranges and physical location of each instrument.

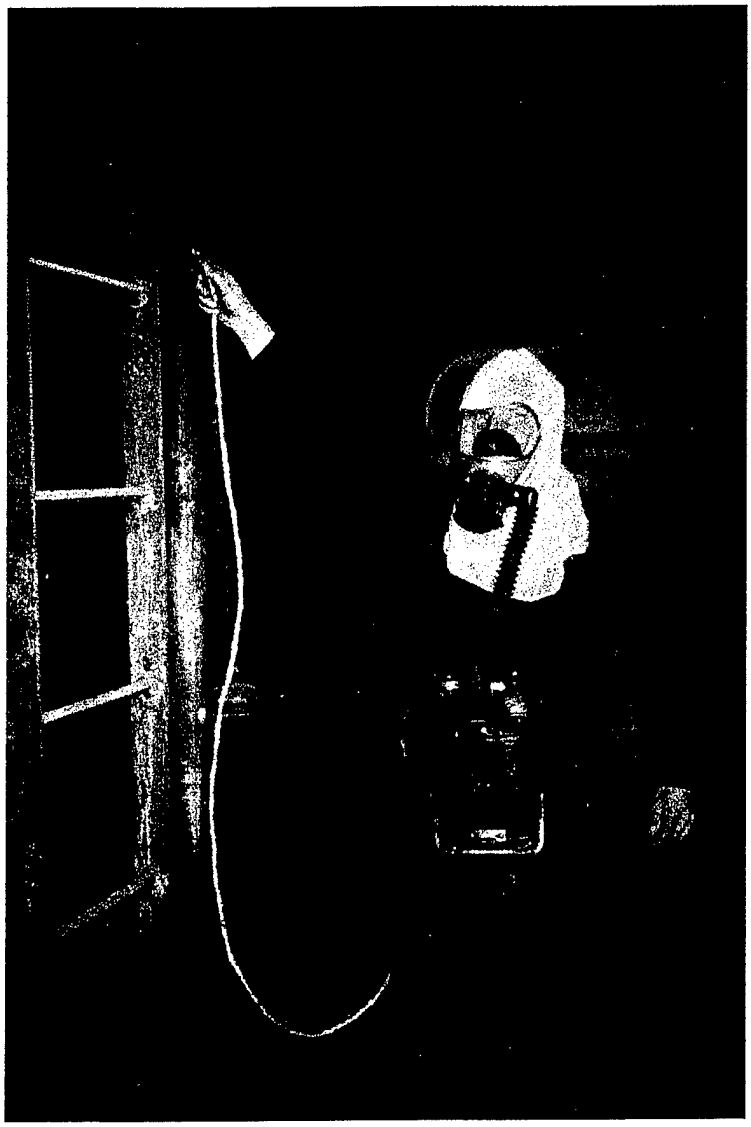


Fig. 3 — Simulated EAB with OBA and rope tether

8.1 Thermocouples

In each compartment, two vertical strings of Type K (Chromel-Alumel) inconel sheathed thermocouples (TC's) were installed, one forward and one aft. On each string, there were six TC's located 0.05, 0.5, 1.0, 1.5, 2.0 and 2.5 m (0.17, 1.6, 3.3, 4.9, 6.6 and 8.2 ft) above the deck. Additional TC's were located in the fuel packages to determine when the fire was extinguished. TC's were also located near bi-directional probes in the ventilation ducts to provide temperature at the measured flow point for determination of duct flow velocity.

8.2 Gas Analyzers

Gas analyzers were used for continuous monitoring of carbon monoxide (CO), carbon dioxide (CO_2) and oxygen (O_2) concentrations. Measurements were made in the forward portion of the Control Room and in the AMR near the Fire Test Enclosure (former water tight door enclosure located between FR 90 and 91) at 1.0 m ($\sim$ 3.3 ft) and 2.5 m (8.2 ft) above the deck. Rosemount Model NGA 2000 gas analyzers were used to measure CO, CO_2 and O_2. The ranges for the carbon monoxide, carbon dioxide and oxygen were 0 to 2.5 percent, 0 to 5 percent and 0 to 25 percent, respectively.

8.3 Load Cell

A load cell transducer (Cooper Instruments Model LFS210 0-136 kg (0-300 lb) capacity) was located in the Fire Test Enclosure to measure the fuel consumption rate of the Class B fire source. Fuel consumption rates were not measured for any of the Class A fuel packages.

8.4 Smoke Obscuration

Smoke obscuration was measured in each compartment using an optical density meter (ODM). ODMs were located 1.5 m (4.9 ft) above the deck in all compartments except AMR where no ODMs were located because of the potential for heat damage due to the close proximity to the fire. Additional ODMs were located 2.5 m (8.2 ft) above the deck in the Control Room, Combat System, Crew's Mess, Wardroom, Crew Living and the Torpedo Room. All ODMs had a path length of 1.0 m ($\sim$3.3 ft).

8.5 Pressure and Duct Flow

Pressure measurements were made using MKS pressure transducers with pressure ranges from 0-50 kPa (0-0.2 in W.C.) to 0-5000 kPa (0-20 in. W.C.). Measurements made included the pressure in the ventilation ductwork, differential pressure between selected compartments and differential pressure of the inside of the boat and ambient. Measurements of the ventilation ductwork pressure were made using bi-directional flow probes.

8.6 Water Pressure and Flow

An ultrasonic flowmeter (Controlotron System 990) was used to measure the total flow rate in liters (gallons) and total flow in ℓpm (gpm) of water used by the hose lines during fire fighting operations. Water supply to the fire main and hose lines was kept constant at 5.5 barg (80 psig) using the SHADWELL fire pump.

8.7 Visual Recordings

Visual recordings were made for all tests. Color video equipment viewed each compartment, except for the Fan Room, Combat Systems and Laundry, including access passageways and the fire equipment locations. Fixed infrared (IR) cameras (Navy NFTI's in protective enclosures) were located in AMR and Laundry to view the fire locations. A portable ARGUS IR camera was used by the safety team to view the fire fighting operations and fire compartments. Monitors and recorders were located in the SHADWELL Test Control Room for each camera.

8.8 Communication Systems

The ship wide 1MC system was extended into the test area for each test. Speakers were located in the Wardroom passageway and in the Torpedo Room so that announcements from the SHADWELL Test Control Room could be heard throughout the test area. The 1MC was used to clear the test area of personnel prior to the test, call away the fire and make announcements during the fire test. Independent two-way communications were maintained between the SHADWELL Test Control Room, Damage Control Central (now referred to as Control Room/DC Central in submarine test area), and test personnel (i.e., Casualty Coordinator, Man in Charge, NFTI operators, and Watchstander) using the ships WIFCOM system and portable radios. One radio channel was used to monitor the fire fighting activities and a separate channel was used to maintain contact with the safety team.

9.0 TEST SETUP

Modifications to the SHADWELL/688 test area were made to create the necessary configuration and ventilation conditions appropriate for AMR testing. In order to more closely simulate an actual Class 688 submarine with narrow passageways, fire fighting equipment and breathing apparatus, the SHADWELL/688 test area was modified to incorporate these fire fighting items. Temporary wooden bulkheads were installed in many compartments to reduce the overall working area. Portable extinguishers, 3.8-cm (1.5-in.) hose stations and OBAs were positioned as near as possible to their realistic location. In some cases, portable extinguishers and OBAs accessible in compartments not included in the SHADWELL/688 mock-up were moved to locations within the test space. This allowed test personnel to retrieve these pieces of fire fighting equipment and use them during fire fighting as would be done in an actual emergency. Simulated

EAB manifolds were mounted in positions within the compartments to realistically simulate, as close as possible, their actual location.

9.1 Ventilation System

The supply and return recirculation ventilation system was extended into the CPO/Crew Mess, AMR and AMR Bilge spaces. This was in accordance with the ventilation system master plan [12]. As in the previous tests, a ventilation scaling factor of 83% was used for the SHADWELL/688 test area. Additionally, an L.P. Blower exhaust terminal was installed in AMR. A damper isolated this terminal from the existing NAV Equipment Room L.P. blower terminal.

9.2 Frame Bay Modifications

Previously, there were no frame bay openings aft of Frame 86 in the SHADWELL/688 test space (i.e., in the NAV Equipment Room, CPO/Crew Mess and AMR). The hull/frame bay configuration in these spaces on a 688 Class submarine is similar to that of spaces forward of the AMR; upper and lower platforms are connected via frame bay openings. These openings by-pass the middle platform as a result of false bulkheads and suspended ceilings installed in the overhead which enclose the middle platform [13]. The AMR is also connected laterally with the Torpedo Room via an opening along the port-side frame bays [14].

Creating frame bay ducting similar to that used in the Laundry and Torpedo Room was problematic from a scheduling and configuration standpoint. In the SHADWELL/688 test area, the AMR is a shared test space; in addition to being part of the SHADWELL/688 test mockup, it serves as a wet compartment for Damage Control testing (see Figure 4). Numerous pipes and mock-ups obstruct areas where frame bay openings would be created. Accomplishing testing in the second and third quarters of FY97 would also be difficult if frame bay ducts similar to those used in the forward SHADWELL/688 compartments had to be designed, fabricated and installed.

To overcome these problems, two temporary frame bay openings were cut in the port side AMR overhead at Frames 89 and 90 (see Figures 5 and 6). These openings allowed smoke to rise into the CPO/Crew Mess, where a 61-cm. (24-in.) diameter flexible metal ducting directed the smoke up through the existing FR89 hatch in the main deck, through the Fan Room and terminated into the NAV Equipment Room. This representation followed the existing frame bays in the Wardroom and Crew Living Compartment, connecting spaces at the upper and lower platforms, while preventing smoke from filling middle platform spaces. The area of the frame bay openings was the same as in the other areas. A hatch cover was fabricated for the FR89 Fan Room hatch to provide a tight seal for the duct connector. A sheet metal door was fabricated to provide an airtight seal for the door (D1) between the Fan Room and the NAV Equipment Room. The temporary frame bay conduit located in the CPO/Crew Mess is shown in Figure 7. Figure 8

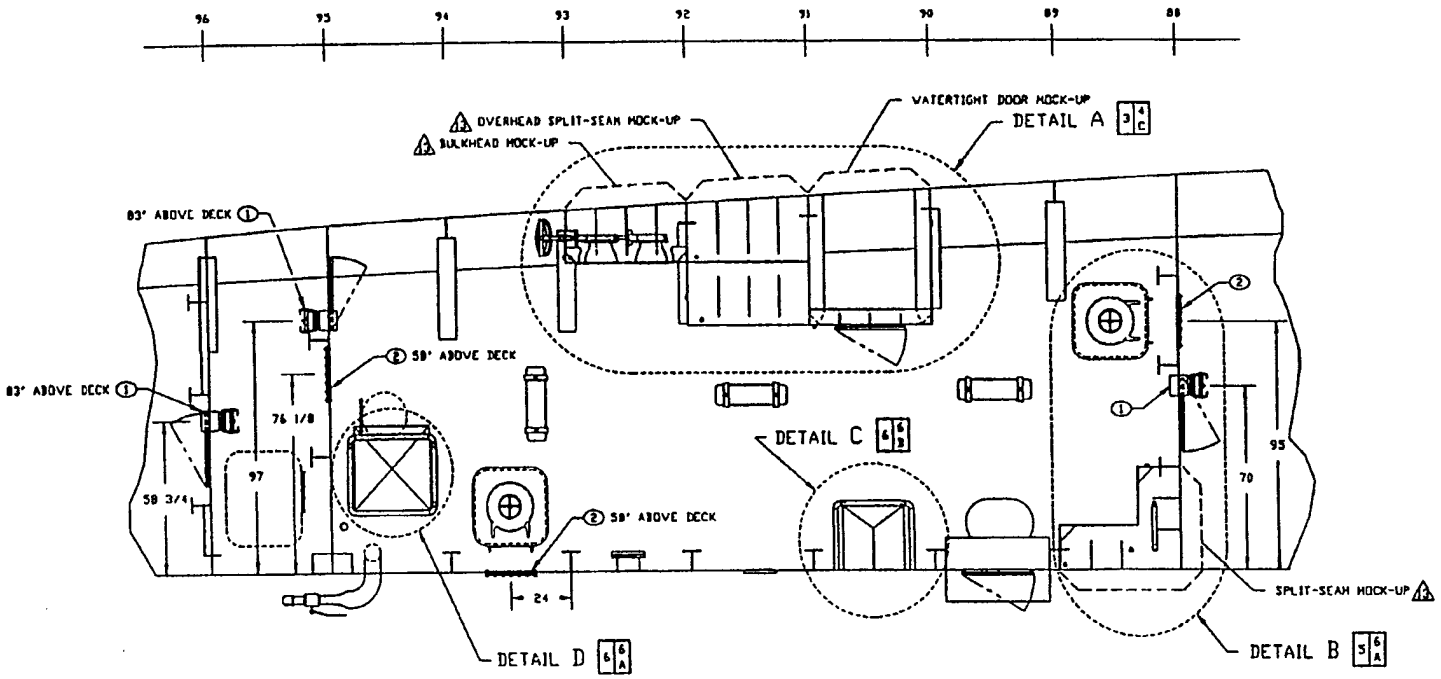


Fig. 4 — Plan view of AMR compartment used as Damage Control Wet compartment

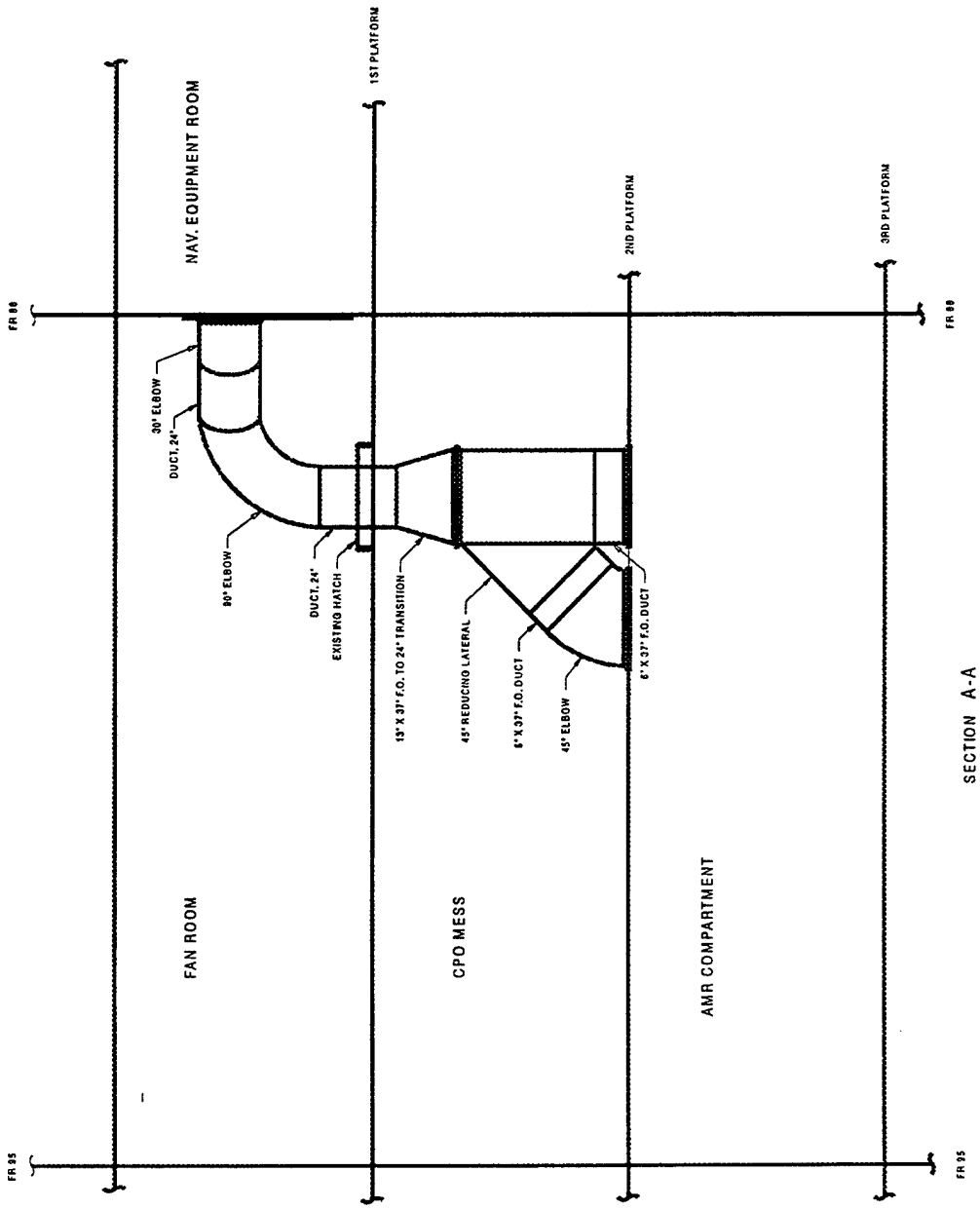


Fig. 5 — Elevation view of temporary AMR frame bay ducting in CPO/Crew Mess

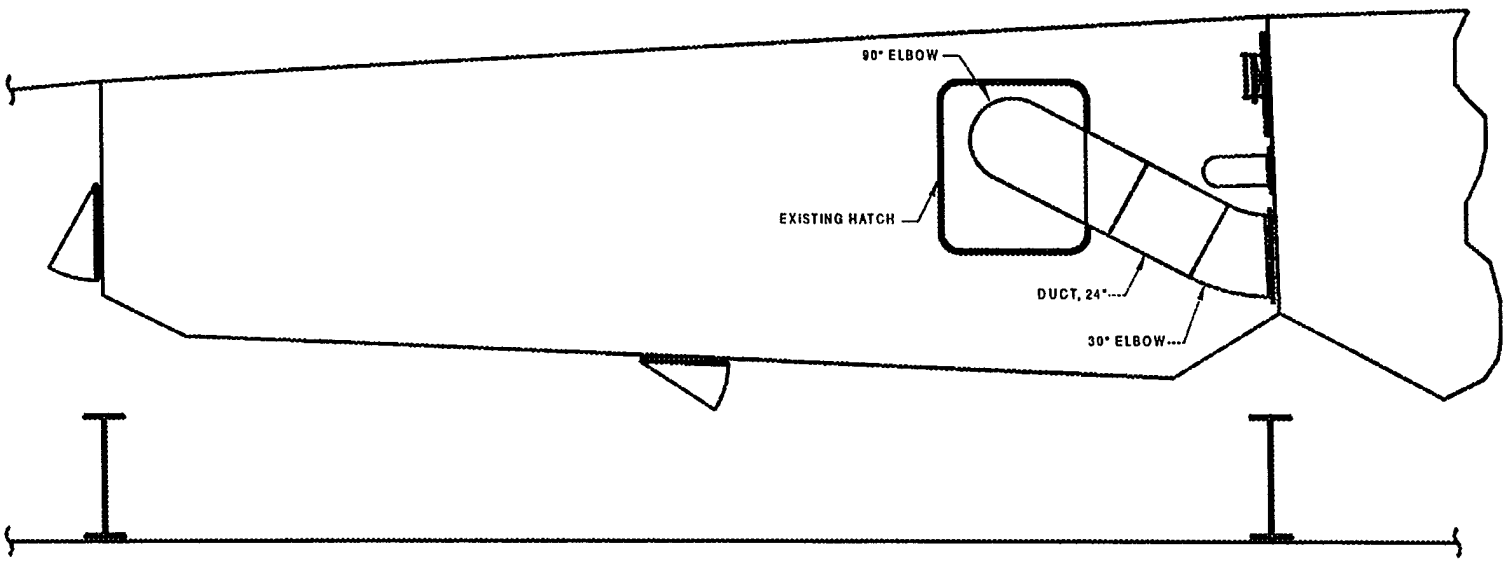


Fig. 6 — Plan vew of temporary AMR frame bay ducting in Fan Room

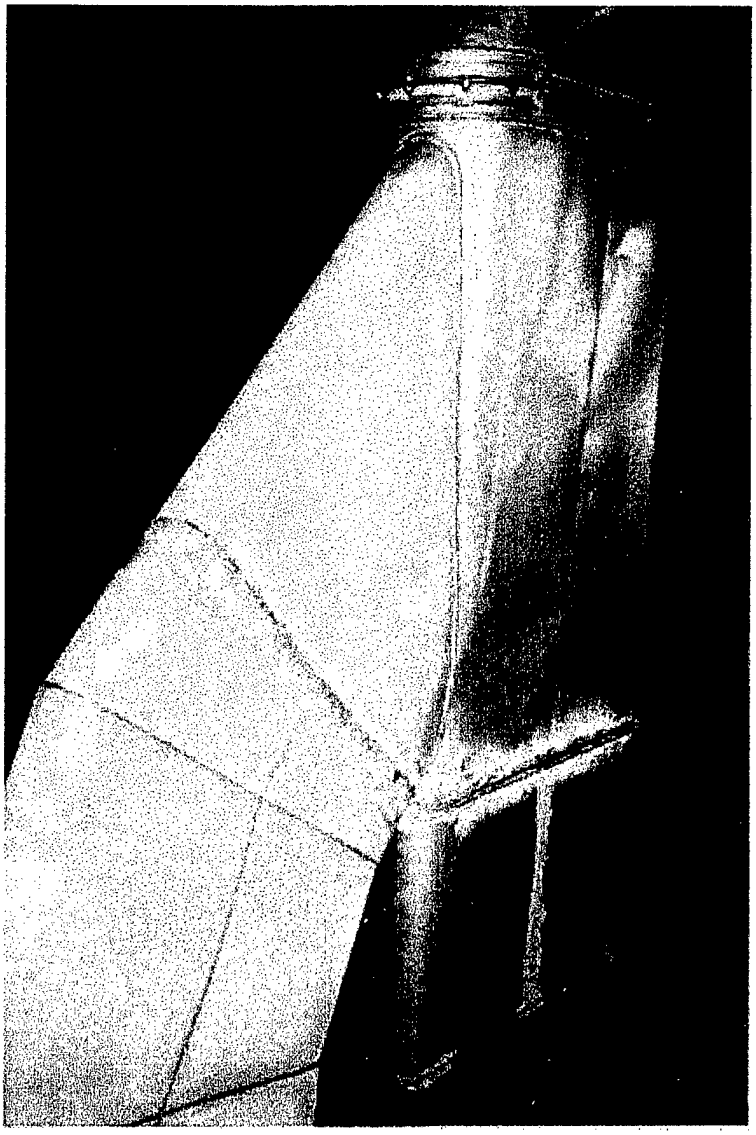


Fig. 7 — View of temporary frame bay ducting in CPO/Crew Mess, forward

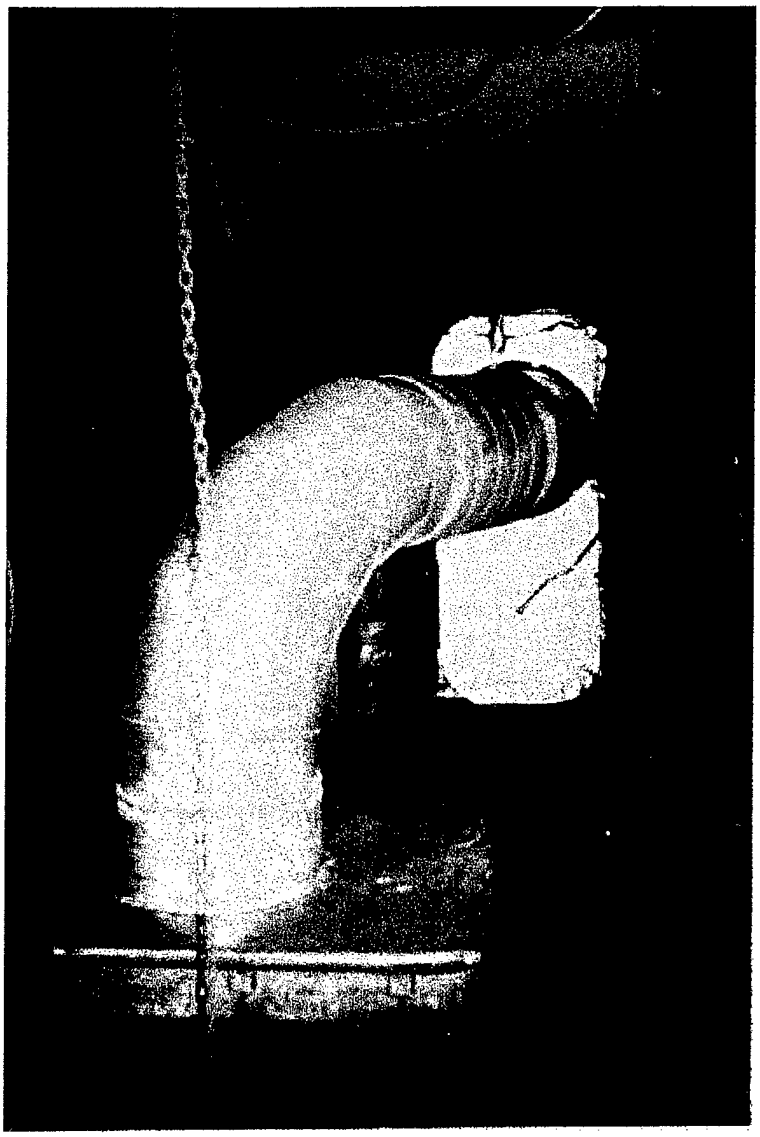


Fig. 8 — View of temporary frame bay ducting in Fan Room, forward

shows the common frame bay conduit in the Fan Room, passing up through the deck hatch, turning and terminating into the NAV Equipment Room.

9.3 Obstructions and Wooden Bulkheads

To simulate the narrow passageways and low overheads found on a submarine, plywood bulkheads and obstructions were constructed throughout the SHADWELL/688 test area. Figures 9, 10 and 11 show plan views of the obstructions and temporary wooden bulkheads for each platform. On the first platform, the Fan Room was not modified since test personnel would not enter this space. The NAV Equipment Room was also unchanged since it was already relatively small with only remote fan controls and an access ladder down to the second platform. All other compartments in the SHADWELL/688 test are were modified as follows.

9.3.1 First Platform

First platform modifications included the Control Room and Combat Systems. In the Control Room/DC Central, eight wooden boxes measuring 0.6 x 0.6 x 1.5-m (2 x 2 x 5-ft) high were constructed simulating electronic equipment and control stations. Four obstructions were placed against each bulkhead, overlapping framebay deck openings. The obstructions did not have a top or bottom on them, so smoke flow through the framebays in the deck was not obstructed. On one of the wooden obstructions along the outboard bulkhead was mounted a gauge panel. The panel contained a red LED temperature display and a Magnahelic pressure gauge. The red LED temperature gauge was connected to a thermocouple (TC) which was measuring the actual Control Room/DC Central temperature. The high side of the Magnahelic gauge was connected to a duct bi-directional flow probe in the ventilation ductwork just outboard of the Control Room/DC Central bulkhead. The gauge panel was used to provide a subjective measurement of the visibility conditions in the Control Room/DC Central as read by test personnel. The port side map table found in a 688 Class submarine was also included in the Control Room/DC Central. The overhead height in the DC Central was not changed from its original configuration. Figure 9 shows the obstructions located in the Control Room/DC Central.

The narrow passageway between the Control Room/DC Central and Combat Systems was simulated with a wooden bulkhead constructed to enclose the ladder access down to the second platform. Two doors were installed into the bulkheads near the access ladder simulating the doors into the Combat Systems/Electronics Space and the AN/UYK-44 Computers Space. The passageway in the Combat Systems Space had an overhead height of 2.0 m (6.5 ft) simulating the realistic low overhead. Figure 9 shows the modifications to Combat Systems.

9.3.2 Second Platform

All three compartments were modified on the second platform. Modifications to the CPO/Crew Mess included the installation of two tables outboard of centerline to simulate

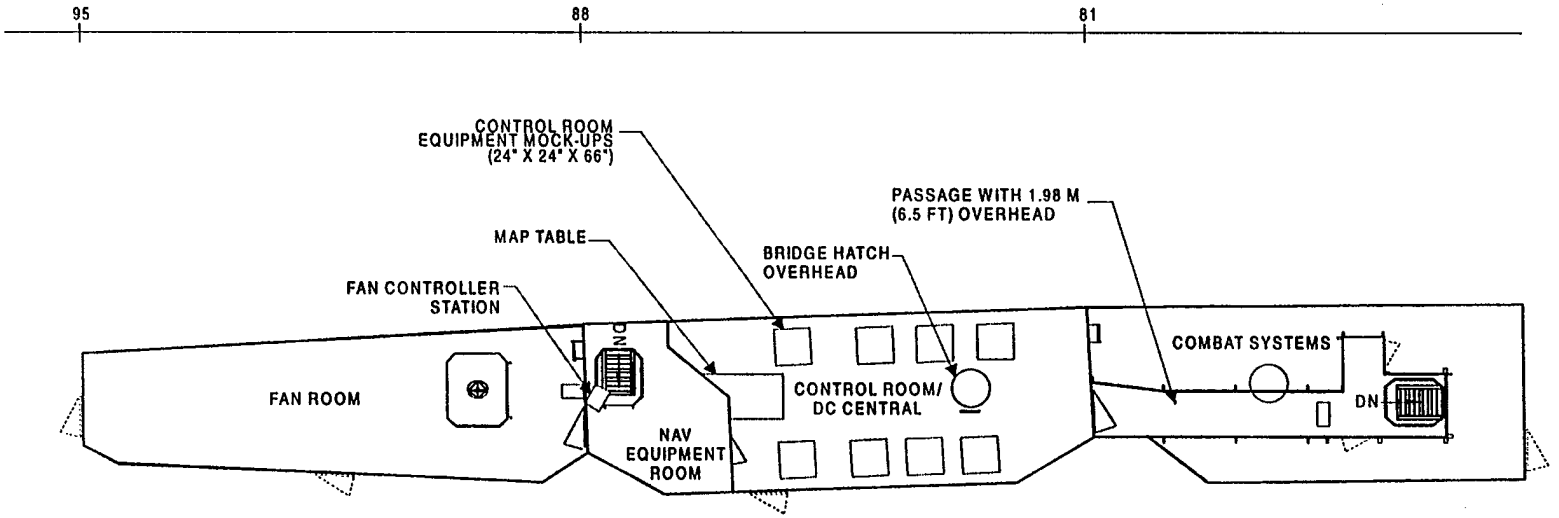


Fig. 9 — Plan view of modification to first platform of SHADWELL/688

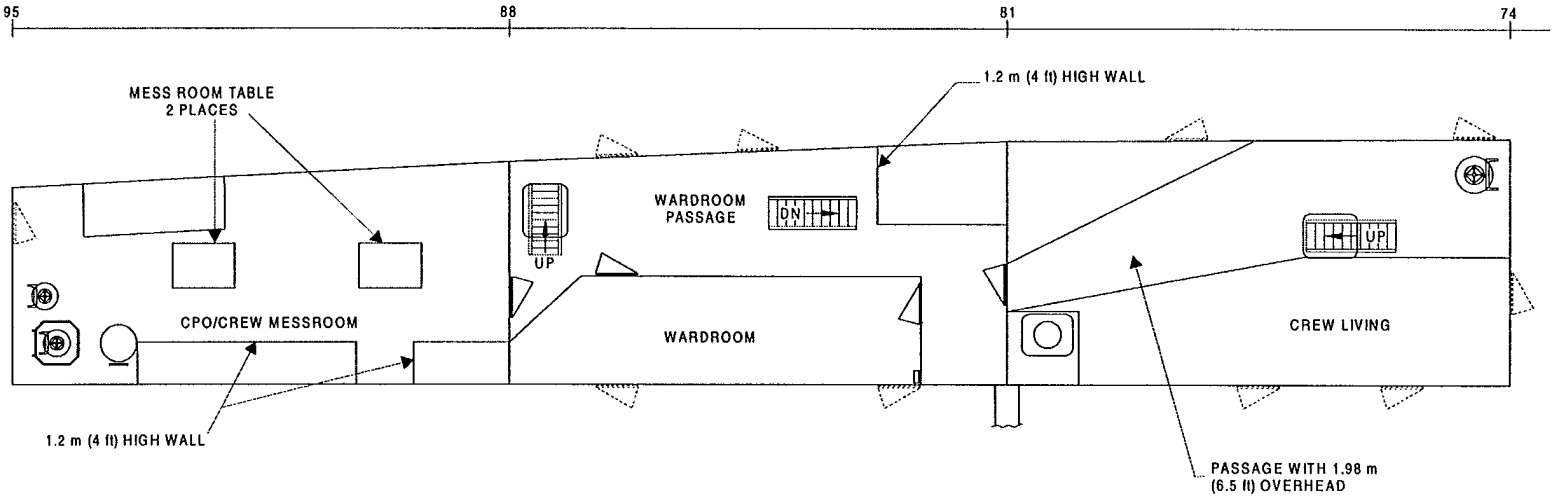


Fig. 10 — Plan view of modification to second platform of SHADWELL/688

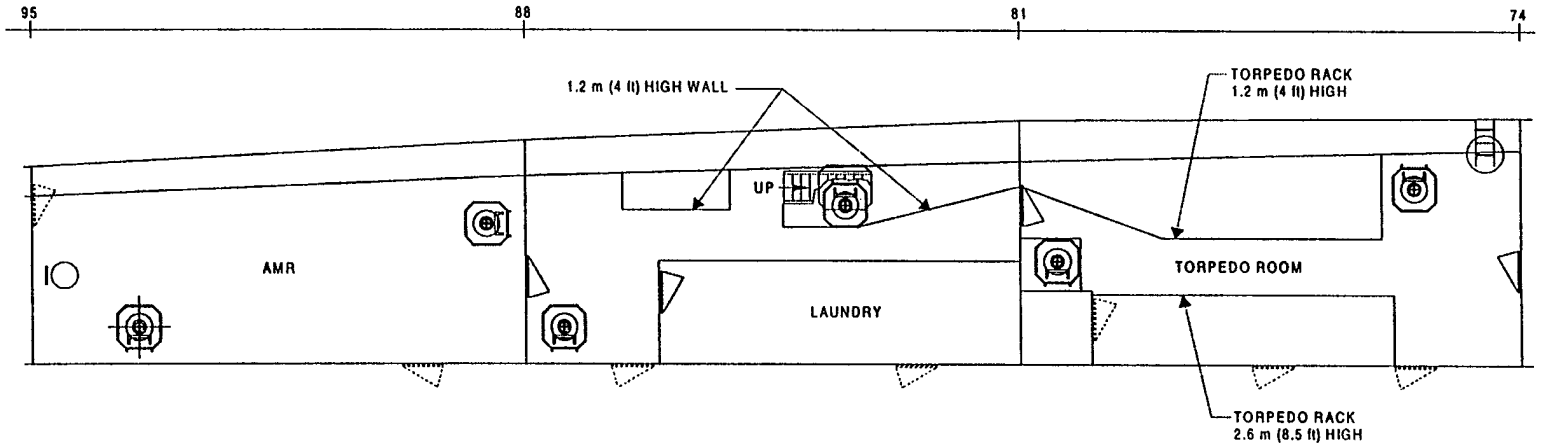


Fig. 11 — Plan view of modification to third platform of SHADWELL/688

mess deck tables where fire fighting personnel would muster and dress out during a fire. Along the inboard bulkhead, a short 1.2-m (4-ft) high wooden bulkhead was constructed with a break, approximately 1.2-m (4-ft) long simulating the entrance into the Galley and Scullery. The wooden bulkhead extended from the forward bulkhead of the compartment aft to an access ladder to the Main deck on the SHADWELL. Figure 10 shows the modifications to the CPO/Crew Mess.

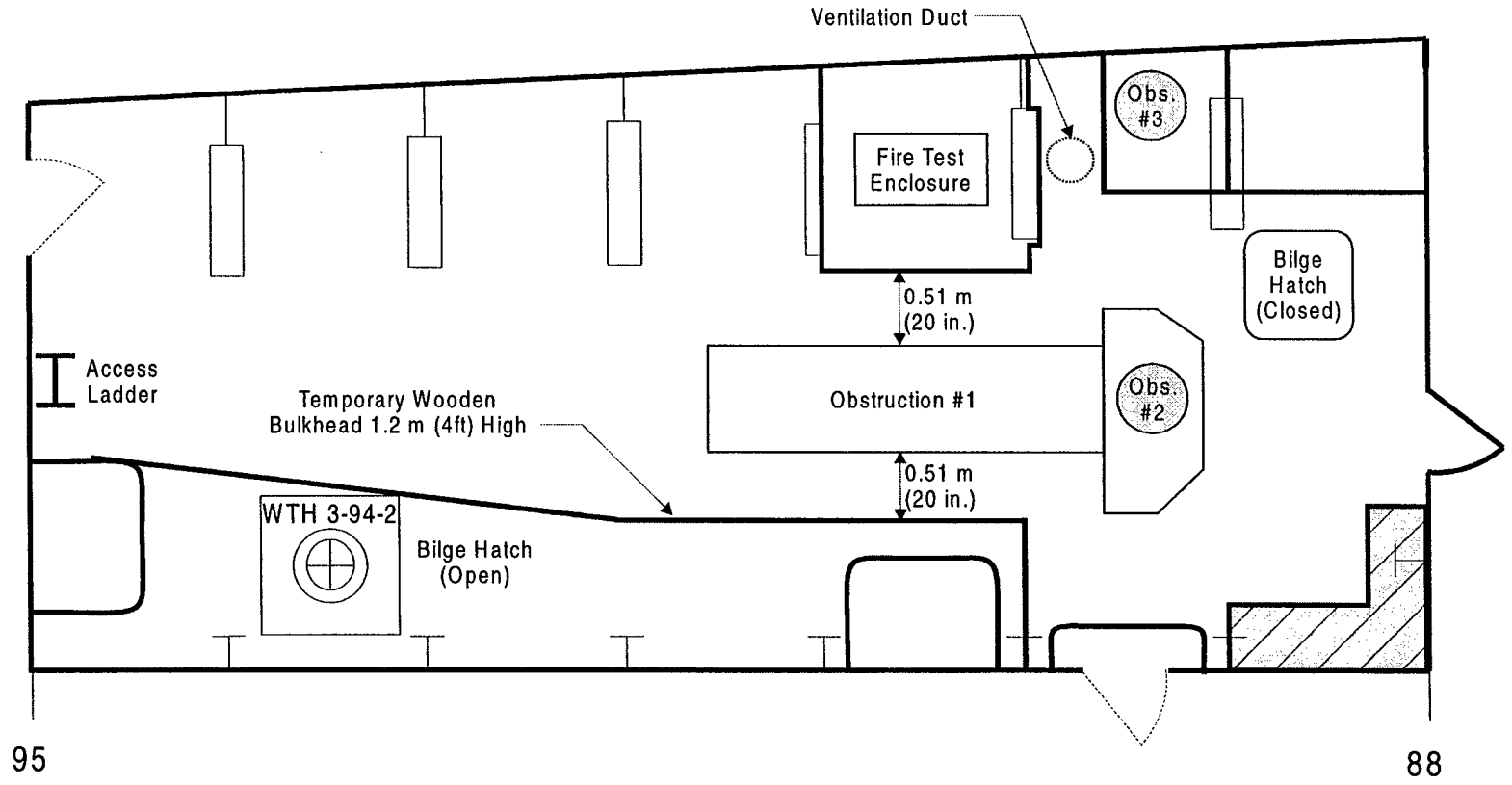
To mock-up the Wardroom, a separate compartment representing the Wardroom was constructed along the inboard bulkhead. The Wardroom was 2.0 m (6.5 ft) wide and ran from slightly forward of the forward most watertight door leading to weather to the aft bulkhead. Two doors allowed entrance into the Wardroom from the mid-platform passageway. Figure 10 shows the modifications to the Wardroom. The aft framebay along the inboard bulkhead was removed and a wooden framebay constructed in its place. This wooden framebay was involved in a number of multi-deck fire scenarios, described later.

The Crew Living space was modified by constructing a wooden bulkhead passageway from the aft end of Crew Living forward, encompassing the ladder down from Combat Systems. The ladder was enclosed on three sides and had a sloped front simulating the realistic enclosure. A short section of wall, 1.2-m (4-ft) high, was placed just aft, running port to starboard, of the scuttle leading down into the Torpedo Room. This represented the scuttle forward of the ladder on a 688 Class submarine. Figure 10 shows the modifications to Crew Living.

9.3.3 Third Platform

All three compartments were modified on the third platform. Obstructions simulating equipment, generators and hydraulic machinery were mocked up and placed in the AMR to make the fire location and fire fighting more difficult, but realistic. To simulate the diesel generator and other large machinery in the AMR space, three steel obstructions were constructed. Figure 12 provides a plan view of the AMR showing the Fire Test Enclosure and the three obstructions. Obstruction 1 simulated the diesel generator and was rectangular in shape having dimensions of 2.1-m (7-ft) long by 0.64-m (2.1-ft) wide. The obstruction was oriented with the long side running forward to aft. The distance between Obstruction 1 and the Fire Test Enclosure was 0.5-m (20-in.). The Fire Test Enclosure after Phase I testing is shown in Figure 13.

Obstruction 2 was a multi-sided steel box which simulated the forward portion of the diesel generator. Obstruction 2 had one long side, measuring 1.04-m (3.4-ft) long with the other sides approximately 0.51-m (1.7-ft) long. Obstruction 2 was oriented with the long side running port to starboard and positioned against the forward edge of Obstruction 1. Both obstructions were 2.8-m (6-ft) high and tack welded to the deck to prevent test personnel from moving them during fire fighting operations. Obstruction 3 was a steel plate which ran from Frame 88 aft to



Note: All obstructions are approx. 2.8m (6ft.) high

Fig. 12 — Plan view showing obstruction in AMR

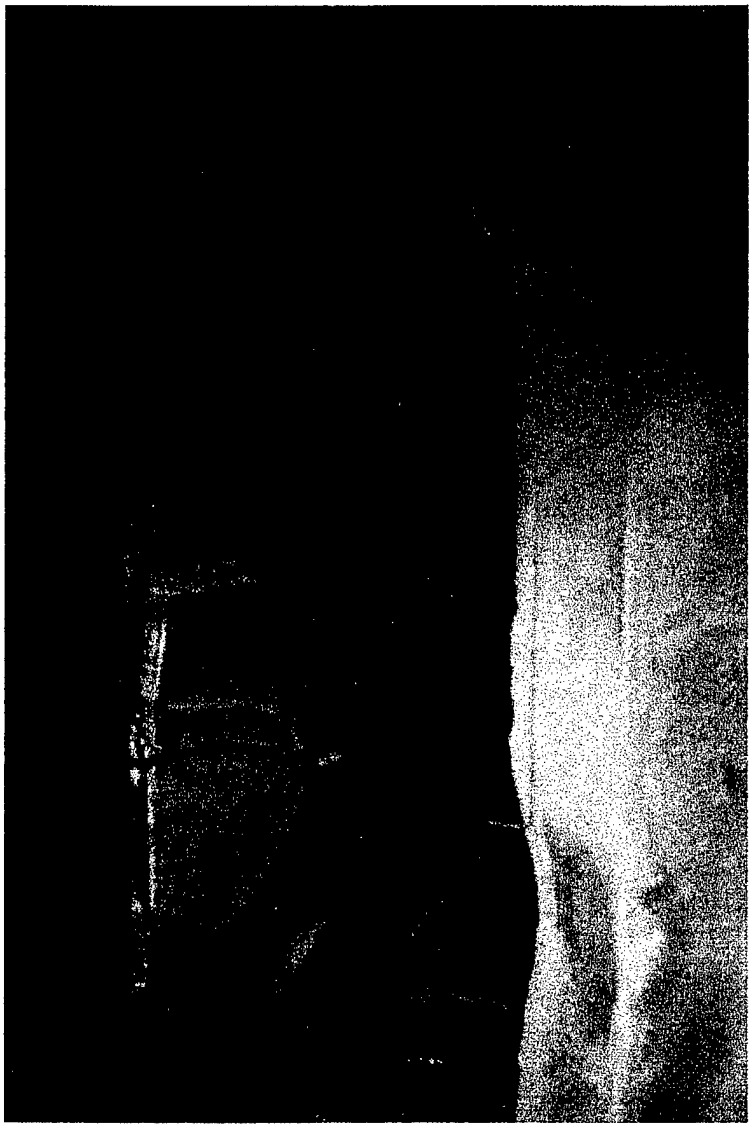


Fig. 13 — View of fire test enclosure in AMR

halfway between Frame 89 and 90. Obstruction 3 was approximately 1.2-m (4 ft) high and 1.8-m (6-ft) long and set inboard of the outboard bulkhead approximately 0.96-m (3.2 ft). Removable sides and a top were constructed forming an enclosed chamber approximately 0.76-m (2.5-ft) square.

Along the inboard compartment bulkhead a 1.2-m (4 ft) high wooden bulkhead was constructed to reduce the passageway width to 0.5-m (20-in.). The wooden bulkhead ran from just aft of the watertight door opening into the welldeck area, aft to an existing metal railing near the escape ladder.

The Laundry space was modified by adding two 1.2-m (4-ft) high walls along the outboard bulkhead as shown in Figure 11. The aft wooden bulkhead enclosed approximately 2 frames just aft of the ladder down from the mid-platform passageway. The forward wooden bulkhead began at the forward end of the compartment and ended at the edge of the ladder. In the Laundry Fire Compartment, three metal cabinets, each approximately 0.61-m (2-ft) wide by 0.30-m (1-ft) deep and 1.5-m (5-ft) high were oriented to make access more difficult and prevent the test personnel from seeing the seat of the fire from the fire compartment entrance.

To simulate the narrow passageways created by the torpedo loading racks, a 1.2-m (4-ft) high wooden bulkhead was constructed on the outboard side of the compartment and a full-height (2.6-m (8.5-ft) high) wooden bulkhead was constructed on the inboard side of the compartment. The passageway between the two wooden bulkheads was 0.74-m (2.4-ft) wide. The short wall simulated an empty loading rack and the full-size bulkhead simulated a fully loaded rack. Figure 11 shows the plan view of the obstructions in the Torpedo Room.

9.4 Portable Extinguishers

Twenty portable extinguishers were positioned throughout the SHADWELL/688 test space. Table 1 shows the number of each type of portable extinguisher and the distribution on each platform. Figures 14 through 22 show the location of each type of portable extinguisher in each compartment. Figure 14 provides a symbol legend for Figures 15 through 22. The AFFF, CO_2 and PKP extinguishers were positioned as closely as possible to the real placement found on a Class 688 submarine. In some cases, the portable extinguishers which would have normally been accessible in compartments not included in the SHADWELL/688 mock-up, were moved to locations within the test space. This allowed test personnel to retrieve and use them during fire fighting as would be done during an actual emergency. In the forward compartment of a 688 Class, there are 10 AFFF extinguishers. Due to supply difficulties, six of the portable extinguishers were real AFFF extinguishers and four were 9.5 ℓ (2.5 gal) water bottles simulating AFFF extinguishers.

SYMBOL LEGEND

AFFF AFFF Portable Extinguisher Location

CO_2 CO_2 Portable Extinguisher Location

PKP PKP Portable Extinguisher Location

W Water Portable Extinguisher Location

V Visual Video Camera (arrow points in viewing direction)

IR Infrared Video Camera

OBA Oxygen Breathing Apparatus Location (with 6 canisters)

● Location of Simulated Emergency Air Breathing Manifold

FFE Fire Fighting Ensemble

¾" HOSE REEL Location of 1.9 cm (0.75 in.) Hose Reel

H 3.8 cm (1.5 in.) Hose Station

Fig. 14 — Equipment and protective gear legend

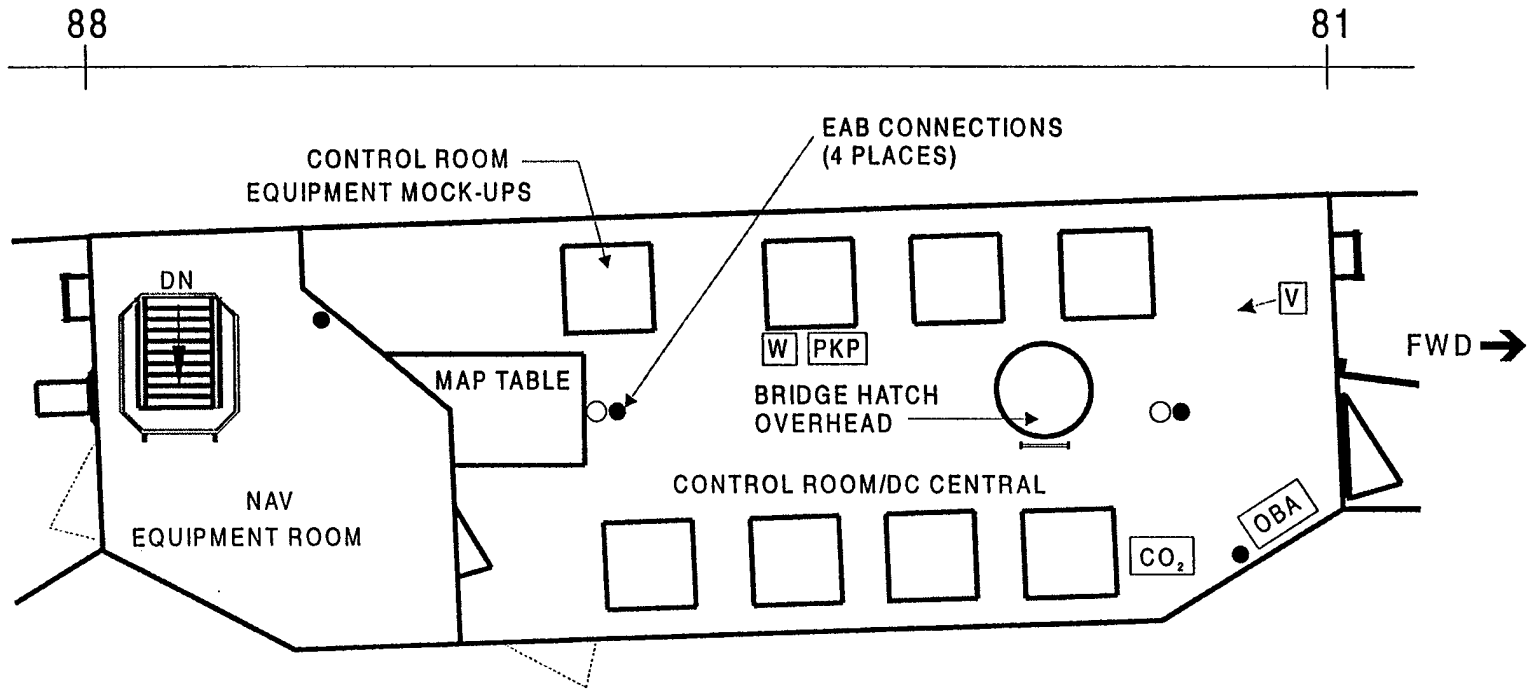


Fig. 15 — Plan view showing equipment and protective gear in Control Room/DC Central

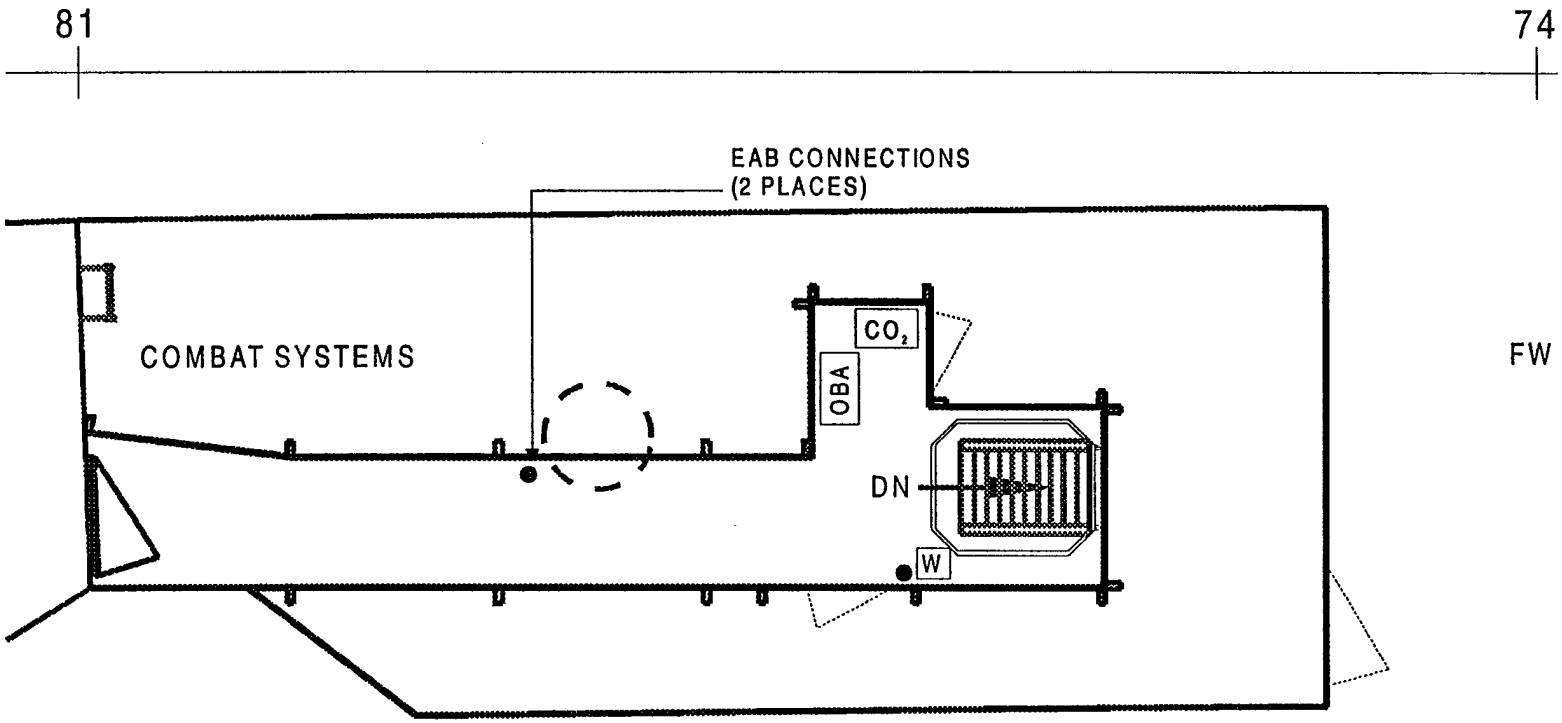


Fig. 16 — Plan view showing equipment and protective gear in Combat Systems

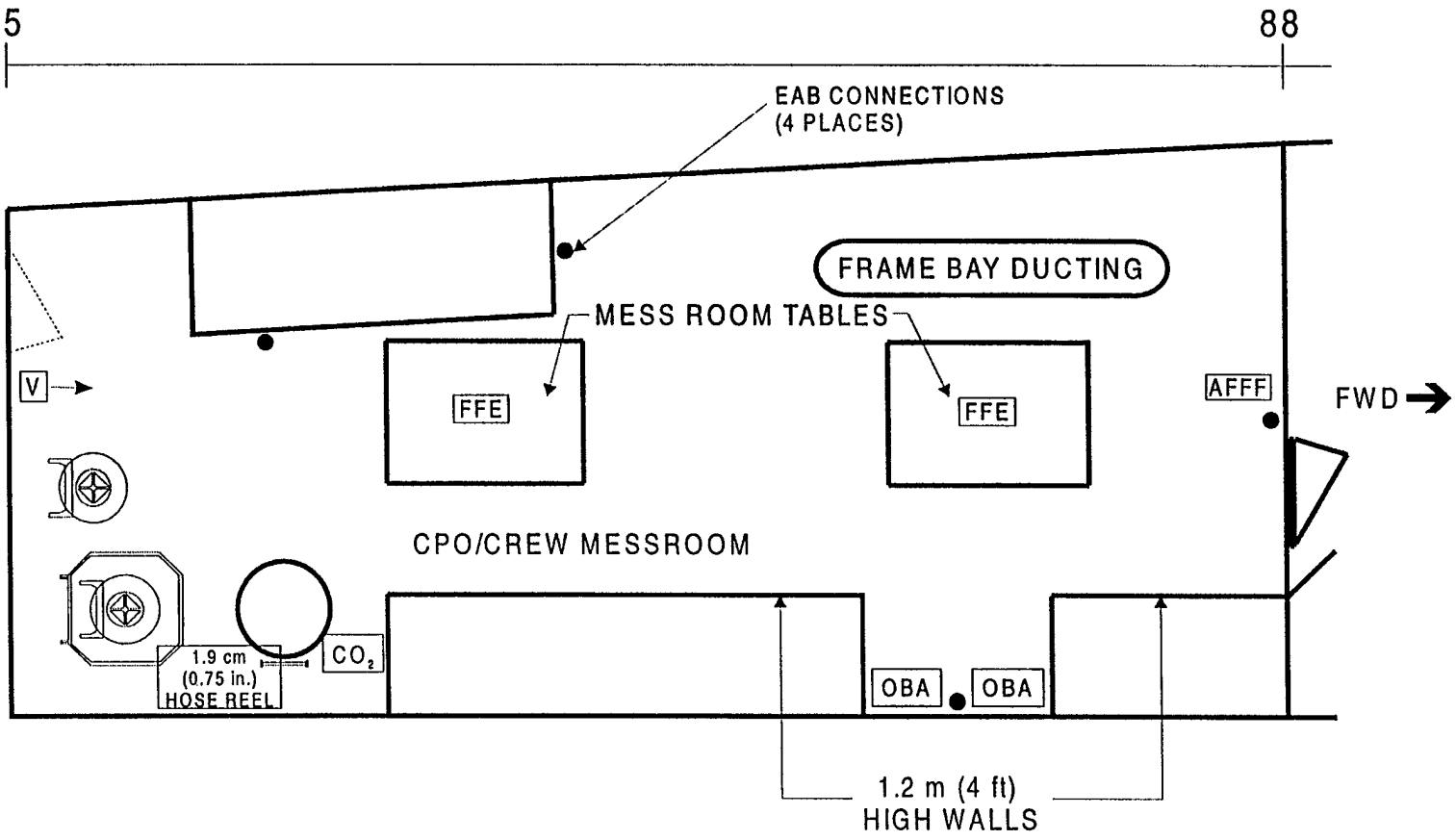


Fig. 17 — Plan view showing equipment and protective gear in CPO/Crew Mess

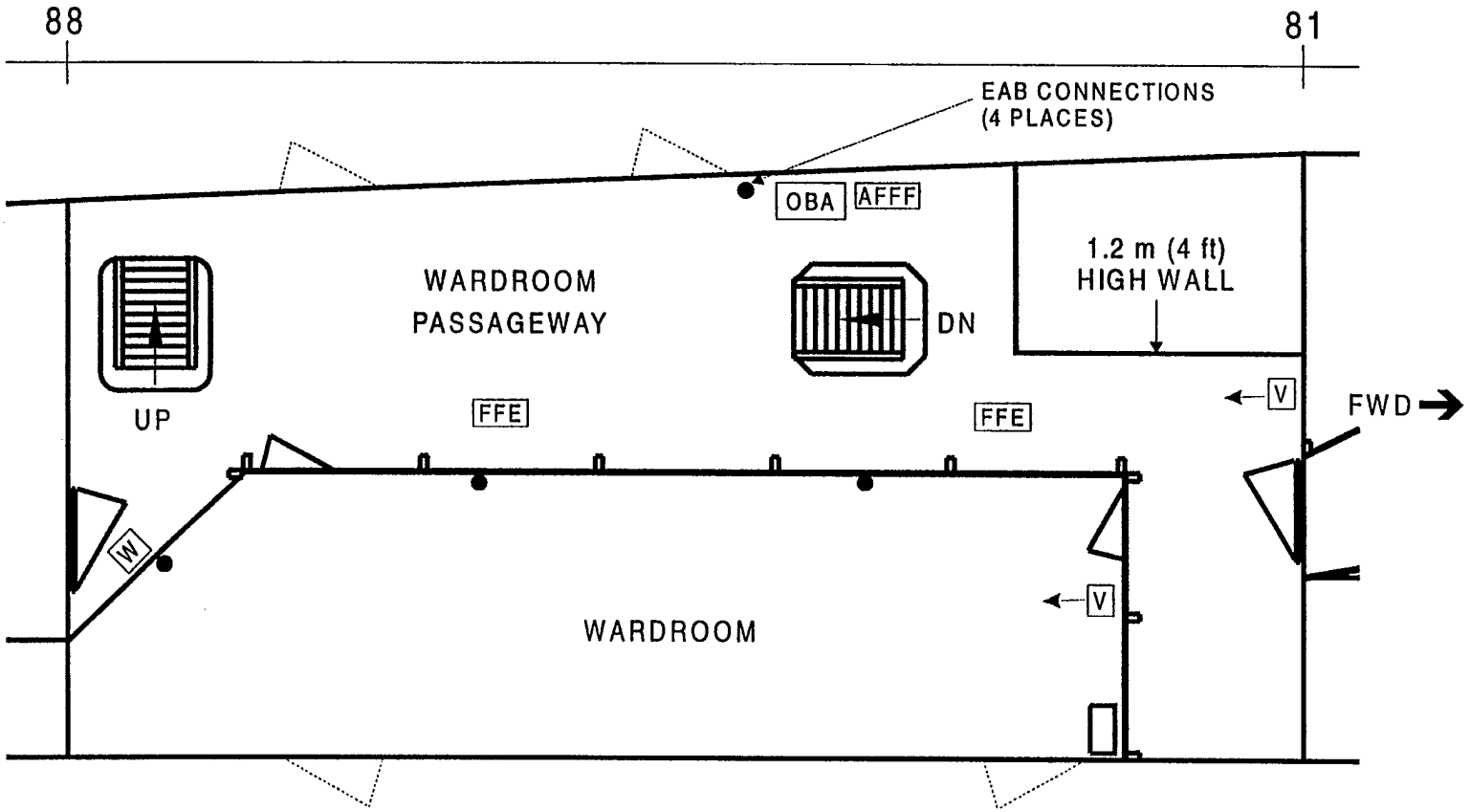


Fig. 18 — Plan view showing equipment and protective gear in Wardroom

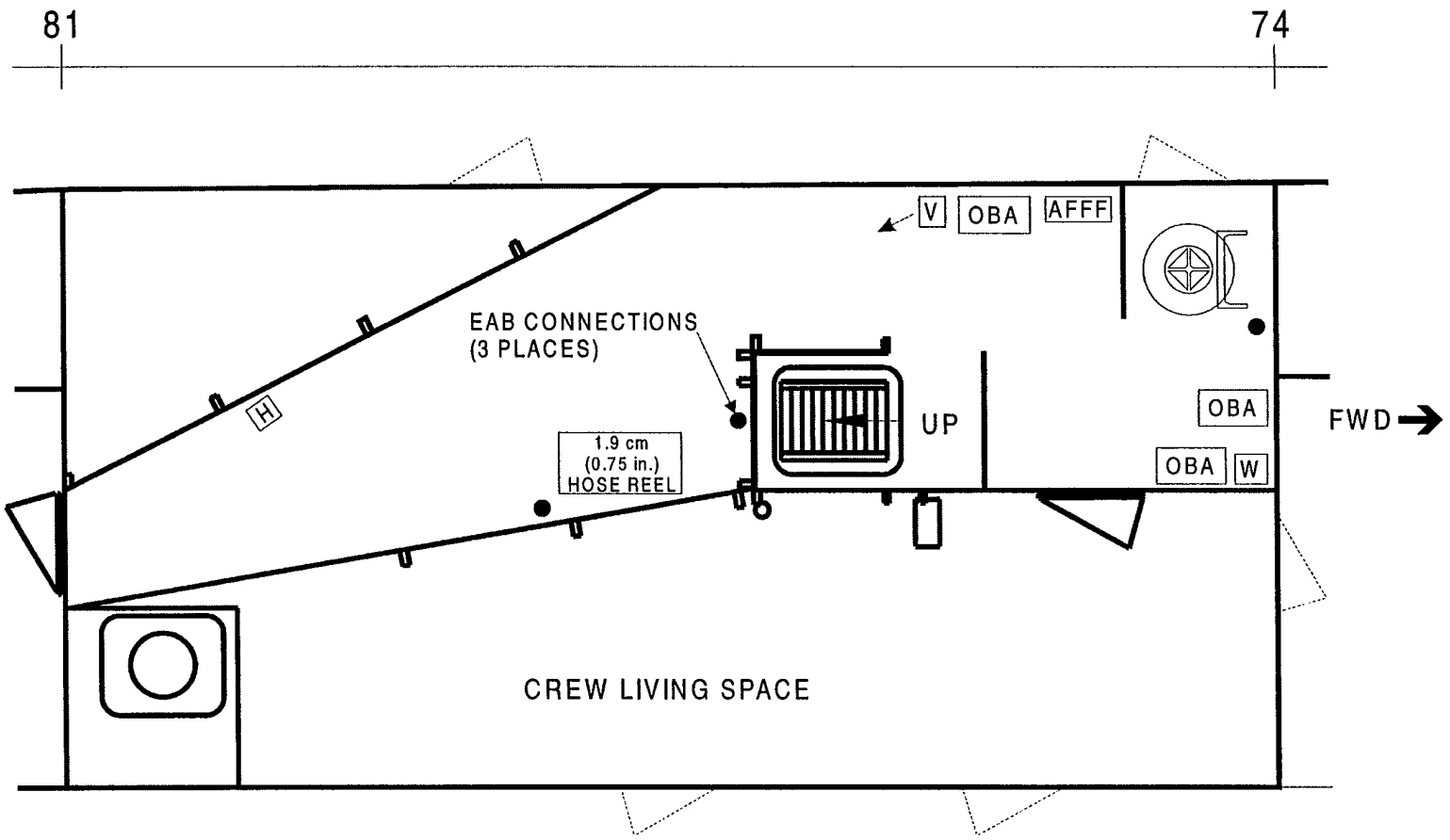


Fig. 19 — Plan view showing equipment and protective gear in Crew Living

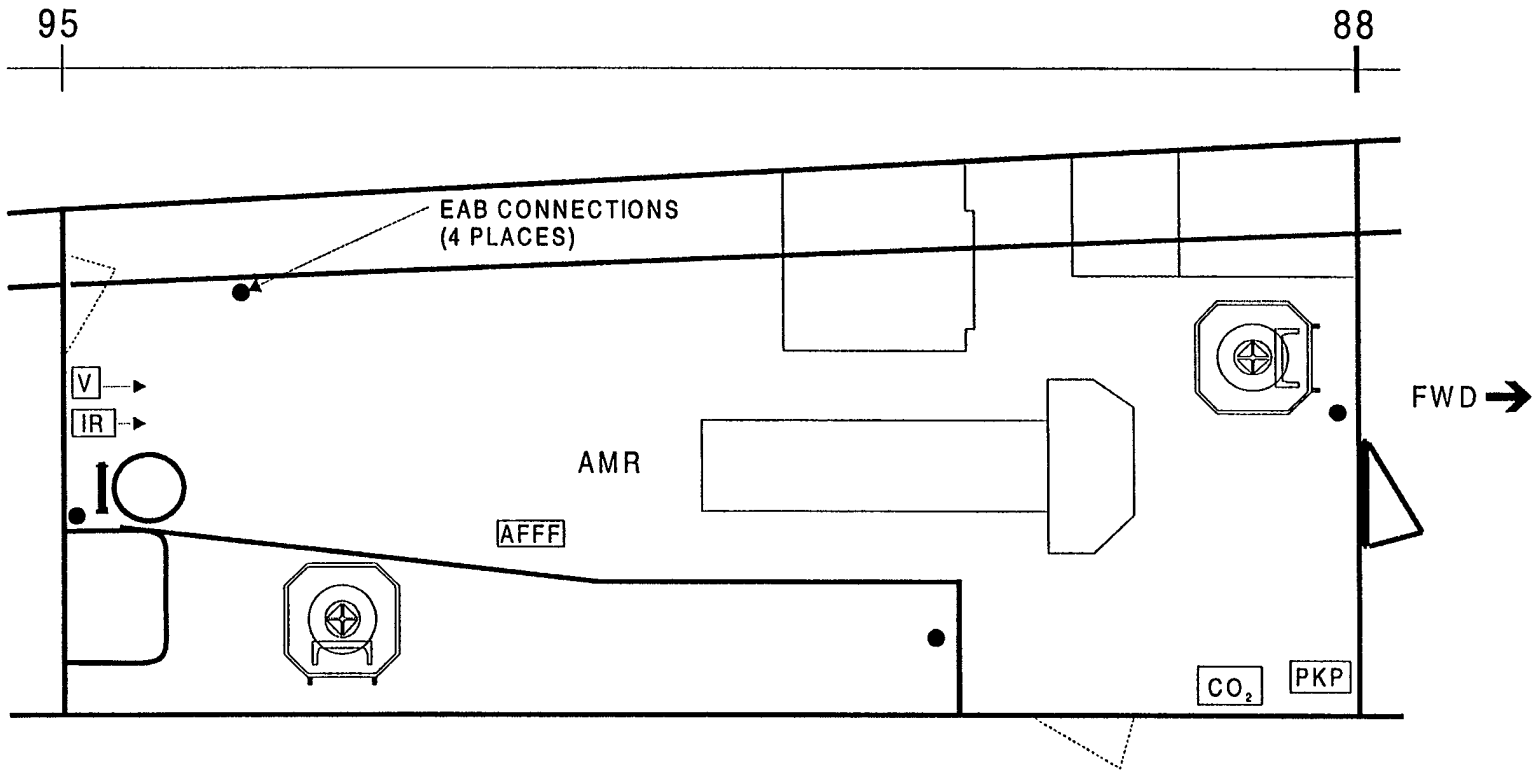


Fig. 20 — Plan view showing equipment and protective gear in AMR

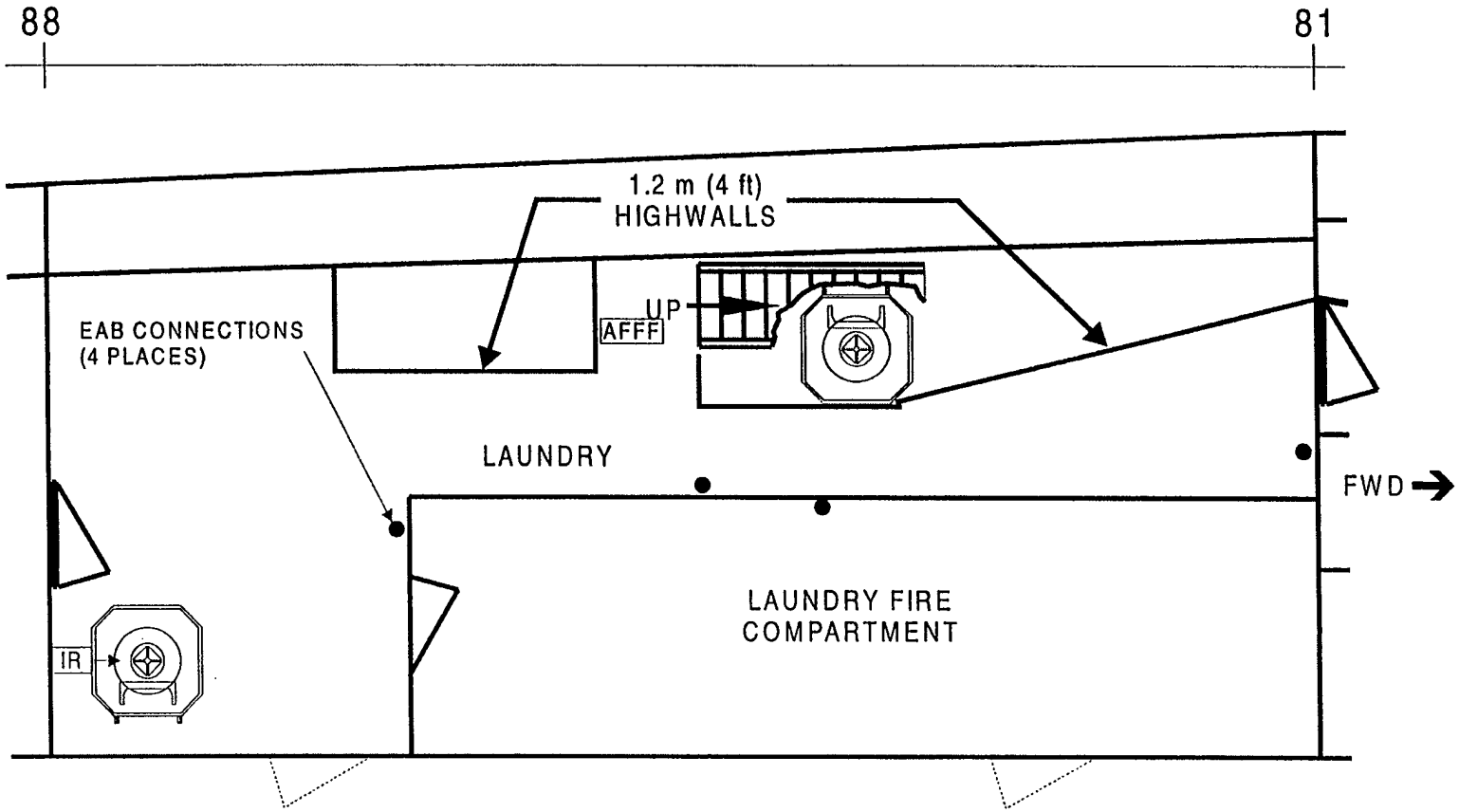


Fig. 21 — Plan view showing equipment and protective gear in Laundry Room

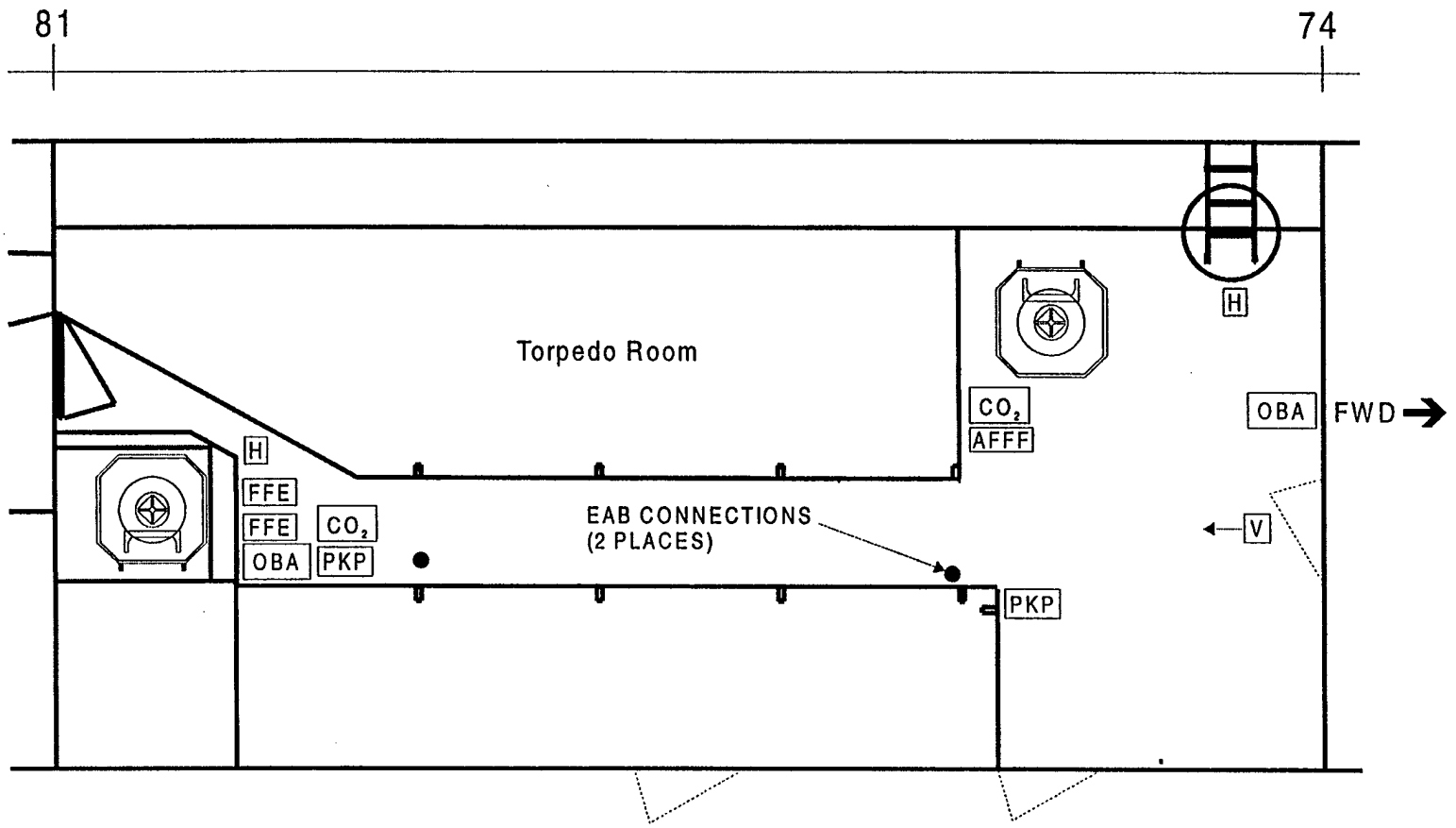


Fig. 22 — Plan view showing equipment and protective gear in Torpedo Room

Table 1. Portable Extinguisher Distribution per Platform

Platform	AFFF	Water	CO_2	PKP	Total
1	0	2	2	1	5
2	3	2	1	0	6
3	3	0	3	3	9
Totals	6	4	6	4	20

AFFF portable extinguishers were charged in accordance with the manufacturer's manual for the Navy premix AFFF extinguisher, Amerex, Model 250N. The extinguisher was filled with 7.6 ℓ (2 gal) of water and 0.95 ℓ (0.25 gal) of MIL SPEC 6% AFFF concentrate. The extinguisher was topped off with water, the cap assembled and the unit pressurized with air to 690 barg (100 psig). The extinguishers were hung from brackets mounted to the wooden bulkheads or steel stiffeners.

9.5 Hose Stations

Three 3.8-cm (1.5-in.) hose stations were installed in the SHADWELL/688 test space to replicate the actual hose stations found on a 688 Class submarine. Each hose station was fitted with one preconnected 15.2-m (50-ft) long section of 3.8-cm (1.5-in.) hose, hung on a camelback and fitted with a vari-nozzle. Another 15.2-m (50 ft) section of hose was also hung on the camelback, but not preconnected. Two spanner wrenches were also positioned at each hose station. One hose station was placed in the Crew Living passageway on the second platform, and two hose stations were placed in the Torpedo Room, one forward and one aft. Figure 19 shows the location of the hose station on the second platform and Figure 22 shows the location of the two hose stations on the third platform.

9.6 OBA Locations

Throughout the test area, ten OBAs were positioned close to their realistic positions. In some cases, the OBAs which would have normally been accessible in compartments not included in the SHADWELL/688 mock-up were moved to locations within the test space. This allowed test personnel to retrieve and use them during fire fighting as would be done during an actual emergency. On an actual 688 Class submarine, there are only eight OBAs in the forward compartment. For safety reasons, two additional OBAs were staged in the test area, thus insuring all participants would have a source of breathing air. Figures 15 through 22 show the placement of the OBAs in each compartment.

On the first platform, one OBA was placed in the Control Room/DC Central representing the actual OBA location. The second OBA was placed at the top of the ladder going down to the

second platform. This OBA would normally be found just outside the Executive Officer's (XO's) stateroom.

On the second platform, two OBAs were placed in the CPO/Crew Mess. One OBA represented the OBA found outside the Dry Provisions Storeroom, and one represented an OBA re-located from the Engine Room for safety reasons. Moving forward, a single OBA was located at the top of the ladder leading down to the third platform. This OBA represented the OBA which would normally be located in the 9-man bunk room adjacent to the ladder, port side. At the base of the ladder coming down from the third platform were three OBAs. One was the OBA normally located outside the Ship's Office, and one was the OBA normally located in the forward crews berthing space. The third OBA was re-located from the Engine Room for safety reasons.

On the third platform, the OBA normally located near the Battery Well Access hatch was relocated to just inside the Torpedo Room and a second OBA was located in the forward part of Torpedo representing the OBA located forward of the Weapons Launch Console.

9.7 EAB Manifolds

The use of Emergency Air Breathing (EAB) apparatus is an integral part of submarine damage control doctrine. Piped, low pressure breathing air was not available for these tests. Both SCBAs and OBAs were used to simulate EABs. To simulate the breathing hose connecting the EAB mask to the manifold and the restricted movement of the wearer, a 2.44-m (8-ft) long piece of 0.6-cm (0.25-in.) diameter nylon rope with clips on both ends was used. The entire length of rope was wrapped with duct tape to make the rope less flexible to simulate the stiffness of the rubber hose. Test personnel who would normally be using EABs (Casualty Coordinator in the Control Room/DC Central, Watchstander and three Rapid Responders) would don the SCBA or OBA prior to the test, but not put the face piece on until they "went on air." Once on air, the personnel hooked their tether to the simulated EAB manifold. This simulated the action of connecting into the manifold and the restriction in movement from the EAB air hose.

EAB manifolds were simulated by four chain links welded to a piece of flat stock with the chain links extending out from the flat stock. Each EAB hookup manifold was approximately 15.2-cm (6-in.) long. Chemlights were attached to all manifolds. As the test personnel hooked into the EAB manifold, they broke the Chemlight to illuminate its location for subsequent personnel to locate in poor visibility conditions. The EAB manifold hookups were mounted to the bulkheads, approximately 1.98-m (6.5-ft) above the deck. Figure 23 shows one of the EAB manifold hookups with a Chemlight attached. The simulated EAB manifolds were positioned approximately 2.44 to 3.0-m (8 to 10-ft) apart. On the deck directly below the EAB manifold hookup, was painted a white square, approximately 0.3-m (1-ft) square. In the white square was either a red rectangle or triangle shaped non-skid strip marker indicating the location of the EAB manifold overhead. The rectangular shaped non-skid marker was approximately 10.2-cm (4-in.)

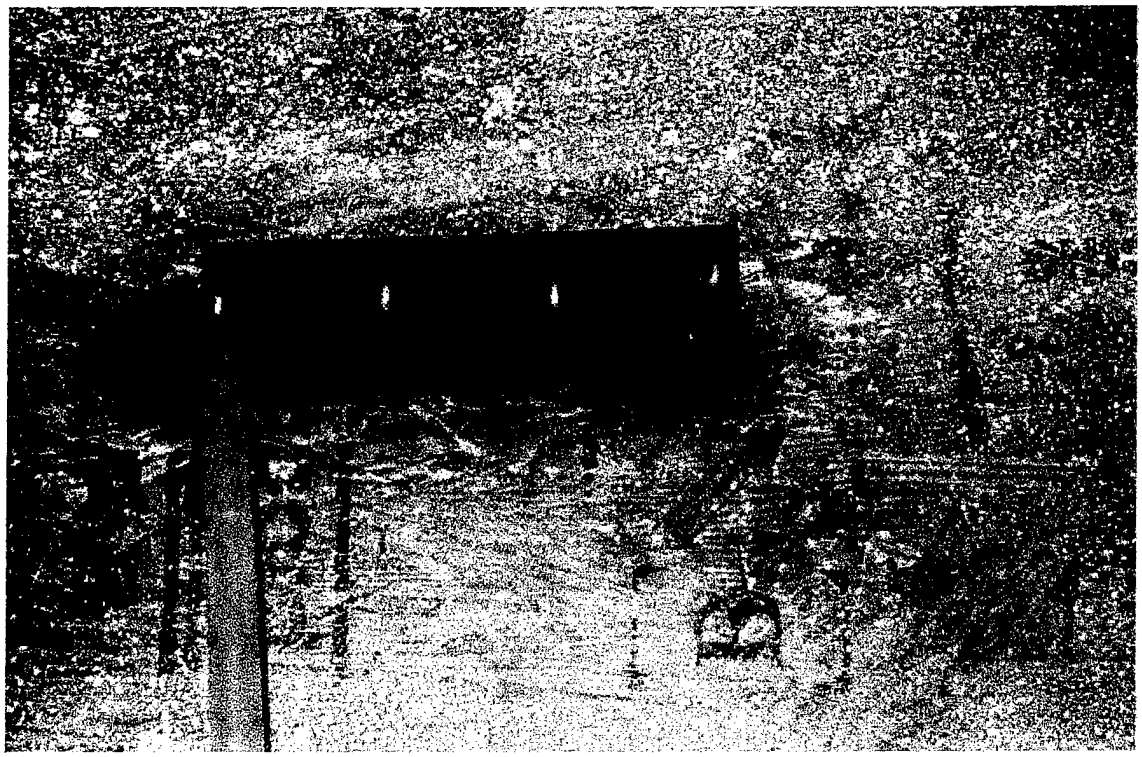


Fig. 23 — View of EAB manifold and Chemlight

wide x 25.4-cm (10-in.) long. The triangular shaped non-skid marker had a base approximately 15.2-cm (6-in.) long with two equal length sides, approximately 20.3-cm (8-in.) long. The location of the EAB manifold hookups are shown in each compartment in Figures 15 through 22.

9.8 Fire Fighting Ensembles

In accordance with standard procedures, four fire fighter ensembles (FFEs) were provided in the test area. Each FFE had a pair of fire fighters gloves, one in each leg pocket. Two FFEs were located in the aft portion of the Torpedo Room, simulating the two located near the ladder down from the second platform, outside Laundry. The remaining two FFEs were located in the CPO/Crew Mess on the second platform. The fourth FFE represented an FFE which was relocated from the aft Engine Room. The four FFEs in the test area provided both nozzlemen and both NFTI operators with an FFE.

Initially, each FFE was folded and placed in a plastic bag simulating normal storage. After the first couple of tests, all FFEs were re-located in the CPO/Crew Mess. The test personnel donned the FFEs prior to the beginning of the test, but their response was delayed for approximately 5 minutes, simulating the time required to don an FFE. Figures 17 and 22 show the location of the FFEs.

9.9 Hose Reels

Although 1.9-cm (0.75-in.) noncollapsable hose reels are not currently installed on 688 Class submarines, two hose reels were installed in the test space to provide the test participants an opportunity to use them in an actual fire exercise. Due to time constraints, the authentic MIL-SPEC hose reels were not available for installation during this test series. As a substitute, fixed CO_2 extinguishing reels were used. Each hose reel was fitted with 15.2-m (50-ft) of 1.9-cm (0.75-in.) noncollapsable hose and MIL-SPEC nozzle. The hose reel located in the overhead is shown in Figure 24. One hose reel was located in the aft, starboard overhead corner of the CPO/Crew Mess and the second hose reel was located in the overhead of the Crew Living passageway on the second platform. Figures 17 and 19 show the placement of each hose reel. Each hose reel was hard piped into the fire main system and fitted with a standard quarter turn valve at the reel. To operate the hose reel, the nozzleman would turn the quarter turn valve pressurizing the hose reel, reel out the amount of hose needed and advance toward the fire. A second hoseman would help reel out more hose as required. This reduced the hose team manning requirements from four personnel to two personnel while providing nearly the same level of fire fighting capability.

10.0 FUEL PACKAGES

Fuel packages utilized in Phase II testing consisted of wood cribs, combustible Class A materials (wood, paper, rubber and excelsior) in the one wooden framebay and a Class B diesel

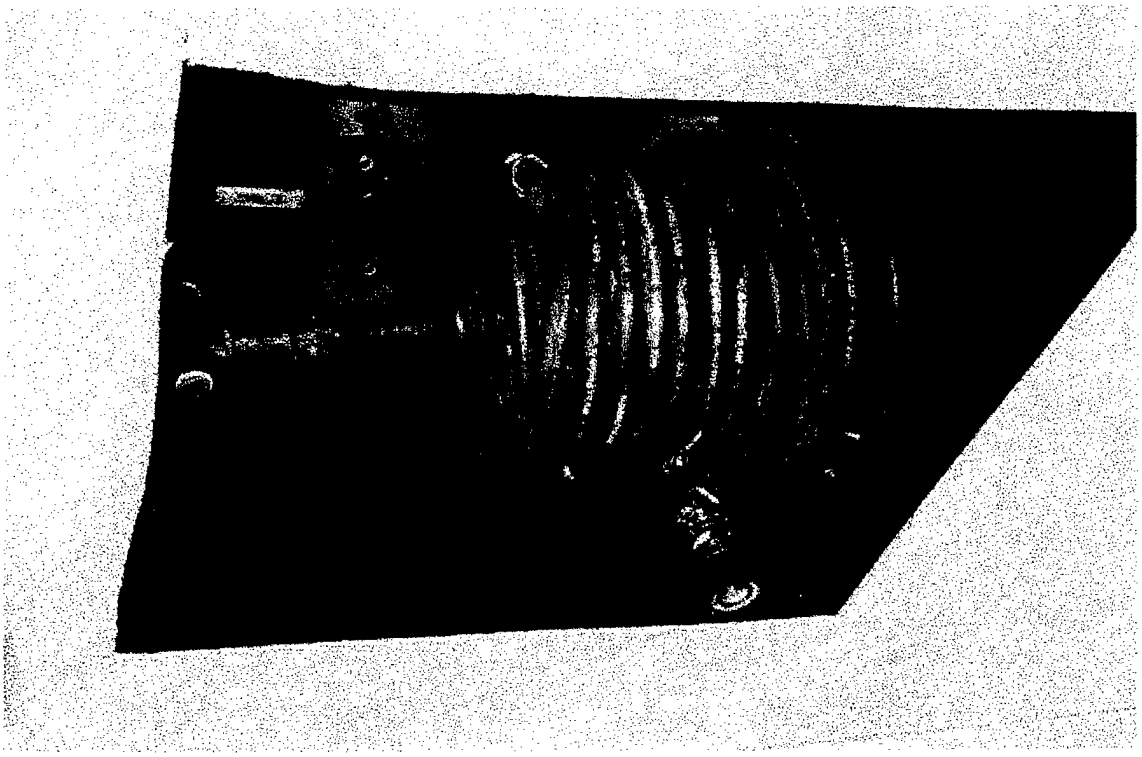


Fig. 24 — 1.9-cm (0.75-in.) hose reel in second platform passageway

pan fire. To generate additional smoke for the Class A fires, a tire was placed on top of the wood crib. The burning tire simulated the type of smoke generated from burning old style electrical cable (MIL-C-915) or PVC-nitrile hull insulation. The wood cribs were ignited using a 0.3-m (1-ft) diameter pan placed under the crib containing a small amount of diesel and/or heptane. The Class B diesel pan fire was ignited by adding a small amount of heptane to the diesel as an accelerant. Figures 25 and 26 show the location of each of the four fire positions used in the test series. Not shown in Figure 25 is the wooden framebay directly above position 1 on the second platform.

10.1 Full Size Class A Wood Cribs

The full size wood crib fuel package consisted of six alternating layers of wood sticks with 5 sticks per layer. Each stick was approximately 3.8-cm (1.5-in.) square and 0.61-m (2-ft) long. The wood crib was constructed on metal grating supported approximately 30.5 to 45.7-cm (12 to 18-in.) above the deck. The initiating fuel pan was placed on the deck, centered directly below the wood crib. A tire was placed on the wood crib to generate additional smoke during the fire.

10.2 Half Size Class A Wood Cribs

The half size wood crib fuel package consisted of six alternating layers of wood sticks. Three alternating layers of sticks were approximately 3.8-cm (1.5-in.) square by 0.3-m (1-ft) long and three alternating layers of sticks were approximately 3.8-cm (1.5-in.) square by 0.61-m (2-ft) long. The wood crib was placed in the top compartment of a three-tiered metal cabinet directly below the overhead opening to the wooden framebay on the second platform. The cabinet was approximately 1.5-m (5-ft) high and raised off the deck approximately 0.3-m (1-ft). Each compartment in the cabinet was approximately 0.9-m (3-ft) wide by 0.61-m (2-ft) deep. The half size wood crib in the metal cabinet is shown in Figure 27.

10.3 Framebay Fuel Package

The aft metal framebay along the inboard bulkhead in the Wardroom was removed and replaced with a wooden mock-up. Class A materials were placed, on the deck, inside the wooden framebay simulating Class A materials normally stored in framebays on a submarine. The Class A materials placed in the framebay included 0.3 and 0.61-m (12 and 24-in.) long sticks approximately 3.8-cm (1.5-in.) square, crumpled newspaper, 7.6-cm (3-in.) wide strips of rubber and excelsior. The wood sticks were stacked on the deck with pieces of crumpled paper and excelsior between wood layers to initiate ignition. The half-size wood crib in the metal cabinet was placed in the Laundry compartment, directly beneath the framebay mock-up. Flames from the Class A fire in the Laundry compartment ignited the materials in the framebay mock-up, presenting the test personnel with a multi-deck fire scenario.

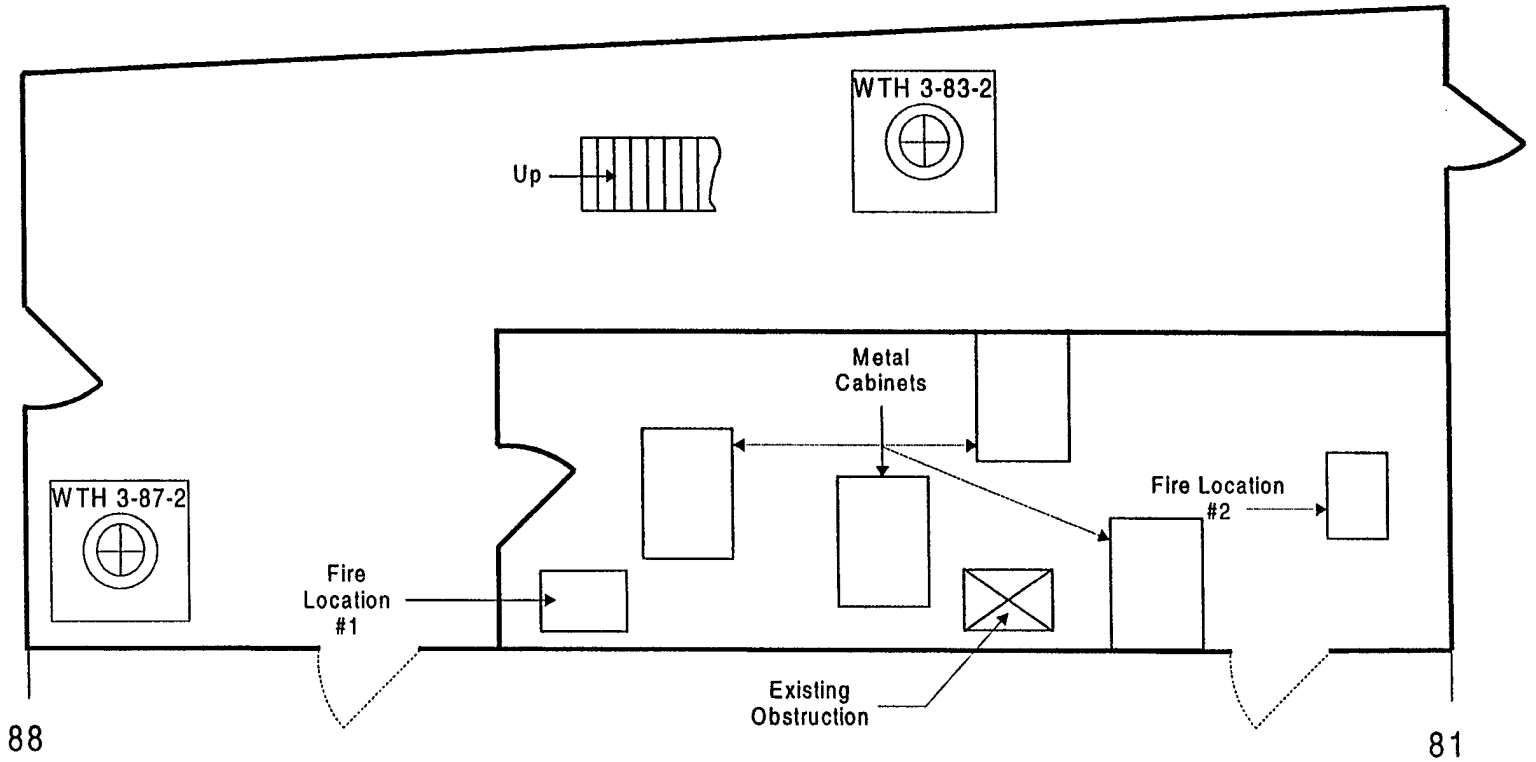


Fig. 25 — Plan view showing fire locations in Laundry

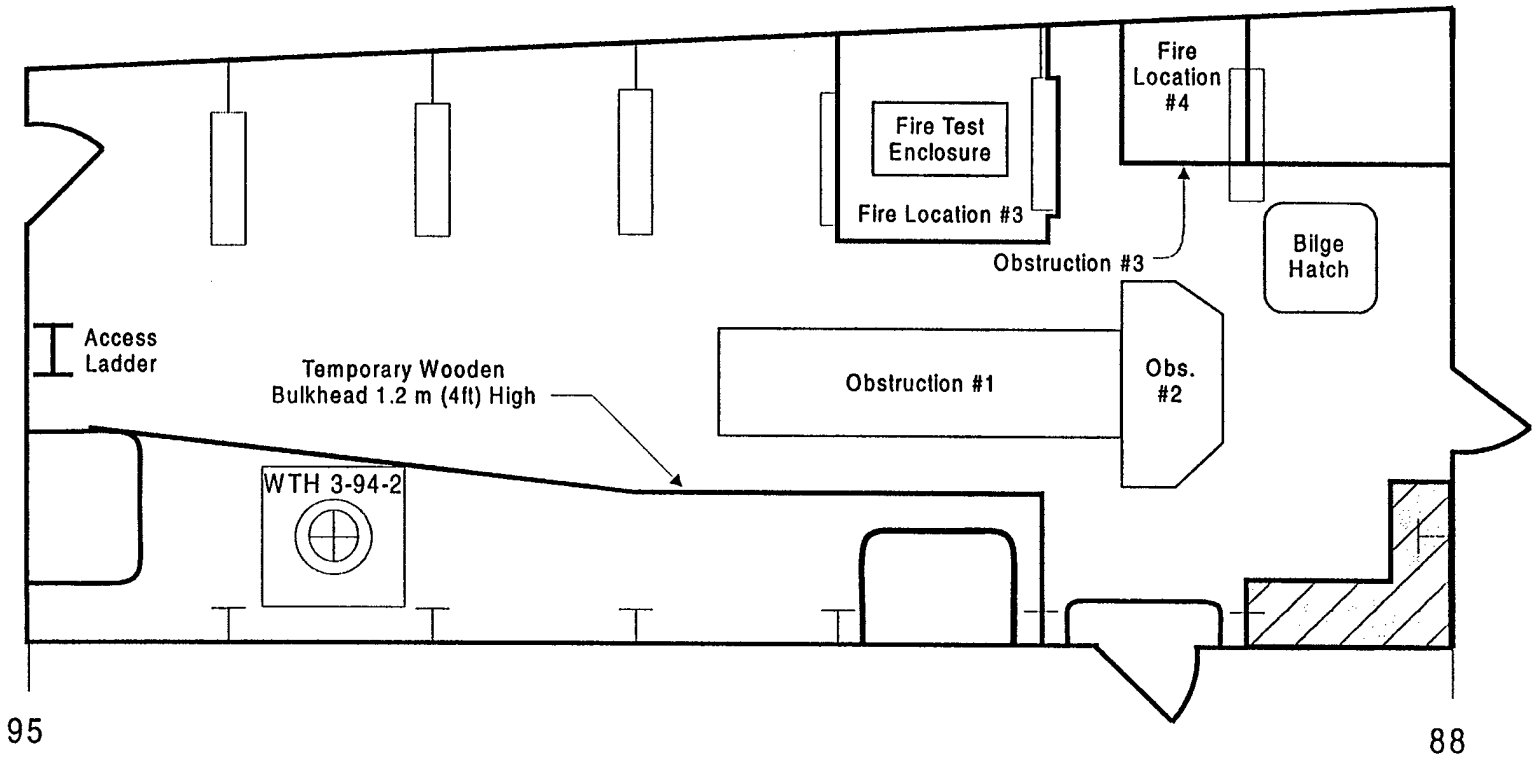


Fig. 26 — Plan view showing fire locations in AMR

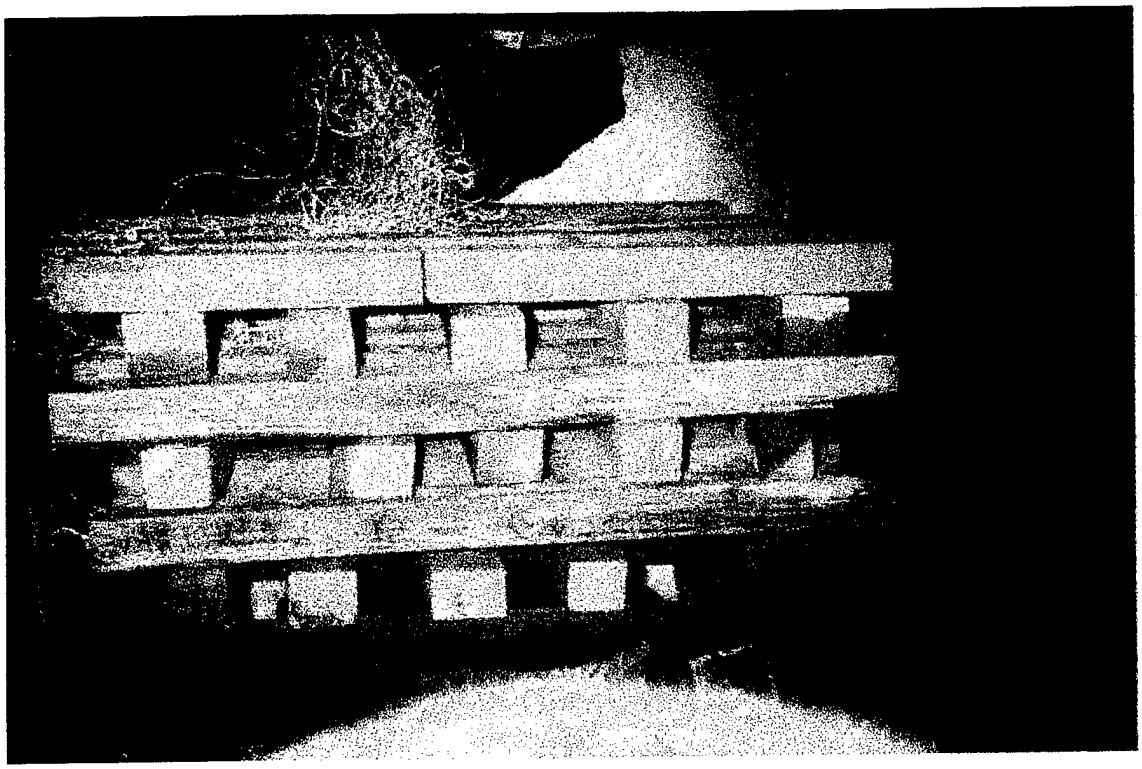


Fig. 27 — View of Class A wood crib in metal cabinet

10.4 Class B Fire Source

The Class B fire scenario used was a 0.51-m (20-in.) diameter steel fire pan filled with approximately 10.1-cm (4-in.) of diesel fuel. A small amount of heptane was added to the test pan to facilitate ignition of the diesel. The 0.51-m (20-in.) diameter diesel pan fire was placed in the Fire Test Enclosure. This pan size produced a fire with a free burning heat release rate of 350 kW (332 BTU/sec) [4].

11.0 TEST PROCEDURE

A total of seven Class A and B fire tests were conducted (Tests sub8_01 through sub8_07). Prior to the test series, personnel were led through the test area to familiarize themselves with the physical layout, the locations of fire protection equipment and the locations of EAB manifolds. At the beginning of the test series, the participants knew only that fires would be initiated on the third platform. As testing proceeded, the participants became more familiar with the locations of the fuel packages.

Upon completion of each test, a debrief was conducted to obtain Fleet personnel feedback and comments. In addition, a debrief of the entire test series was conducted at the end of the test week.

11.1 Initial Conditions

Prior to each test, the test personnel had preassigned responsibilities, e.g., Watchstander, Rapid Responders, Hose Team, NFTI Operator, Man-in-Charge or Casualty Coordinator. A Watch Bill was posted for each test and is found in Appendix C. The same personnel were used in all seven tests. The positions of the Watchstander, Rapid Response Teams and Hose Teams were rotated to give all test participants the experience of each position/station. The only two positions which remained constant for all tests were the Casualty Coordinator in the Control Room/DC Central and the Man-in-Charge.

Immediately prior to each test, all test personnel entered the SHADWELL/688 test area. Once all test participants were inside the test area, all exterior hatches and doors were closed simulating the closed boat. Also inside the SHADWELL/688 test area were four safety team members. One safety member was positioned in the Control Room/DC Central and one was positioned in the CPO/Crew Mess. Both of these safety team members remained at those positions during the entire test. On the second platform was one safety team member with an ARGUS IR camera, tethered to provide real time pictures back to the SHADWELL Test Control Room, but free to roam with the fire fighting teams and one on the third platform free to roam with the fire fighting teams.

For safety reasons, the induction valve located in the main sail was left open during all tests, preventing a pressure buildup inside the test area. In the event of an emergency, the safety team would not have to wait for the pressure to equalize prior to removing a test participant from the test area to weather.

Test personnel were pre-staged in the CPO/Crew Mess prior to the fire ignition, the normal damage control team staging area. Personnel donned, or partially donned, the protective gear that would be used for their assigned fire party position.

Two minutes of background data were taken before the fires were ignited. Prior to igniting the fire, the ventilation system was initially operating in recirculation mode (the normal submerged mode of operation). The SHADWELL fire main pressure was initially set at 2.4 to 2.8 barg (35 to 40 psig) to represent the normal trim header pressure. After the Test sub8_03, the fire main pressure was initially set at 5.5 barg (80 psig) and remained there for the entire test. The time delay to raise the pressure was simulated during the test evolution. This was done to reduce the number of actions necessary in the SHADWELL Test Control Center during the tests.

When all personnel were in place and ready, the accelerant (heptane) was poured and the fire(s) ignited. Data were recorded so that ignition time was 0:00. The time of ignition was recorded by using either the visual or IR cameras or it was reported over the radio by the Safety Team.

11.2 Test Event Timing

Test duration was generally 30 minutes. The test personnel typically required 10 to 15 minutes to extinguish the fire. All tests were generally continued for 15 to 20 minutes after the fires were extinguished by the fire fighters to evaluate the effects of the ventilation scenario. Test events not executed directly by fire fighters, such as controlling ventilation and simulated operation of the submarine, were performed at times representative of the operation of a submarine. The baseline for the timing of such events was the announcement of the fire over the general announcing system (1MC), which occurred after the report of the fire by the Watchstander. Test events executed directly by the fire fighters were not controlled and occurred as the fire fighters performed them.

The timing of test events was controlled as follows:

- **Fire Announced.** Typically, approximately one minute elapsed from the time the Watchstander was dispatched to find the fire (smelled smoke or heard announcement) until the time the fire was reported by the Watchstander to the Casualty Coordinator in the Central Room/DC Central and announced over the general announcing system (1MC). The Watchstander reported the fire to the Control Room/DC Central over a portable radio. The Casualty Coordinator in turn reported the fire to the SHADWELL Test Control Center and requested the fire be called away over the 1MC.

During Tests sub8_01, sub8_02 and sub8_03 personnel responded as they would on a submarine, i.e., when they saw or smelled smoke. After Test sub8_03, the Watchstander was released approximately 2 minutes after the fire was ignited from the CPO/Crew Mess when he heard the announcement over the 1MC, "Watchstander investigate the source of smoke in the forward compartment." The delay was incorporated into the test sequence to allow all fires to be ignited and become established to present the fire fighters with a more challenging fire threat.

In Tests sub8_06 and sub8_07, the Watchstander and the Rapid Response Team were delayed for a predetermined time to account for delays in donning protective equipment and discovering the location of the fire. This was necessary because the test personnel were becoming familiar with the test scenarios and the locations of the fire. The sequence of events for Tests sub8_06 and sub8_07 can be found in Appendix D.

- **Fire Main Pressurized.** Thirty seconds after the fire was called away, "The fire main is pressurized," was announced over the 1MC. This indicated to test personnel that the fire main pressure was increased from the normal 2.4 to 2.8 barg (35 to 40 psig) to 5.5 barg (80 psig).

- **Ventilation Secured.** One minute after the fire was announced, ventilation was secured in all tests.

- **Submerged Scenarios.** For Tests sub8_01 through sub8_03, where the boat was initially submerged and rose to periscope depth, a 10 minute minimum delay in commencing ventilation was used. This delay represented the approximate time required for personnel to align valves and dampers, set ballast tanks and for the boat to ascend to the proper depth before ventilation could commence. Commencement of ventilation was left to the discretion of the Casualty Coordinator.

- **Periscope Depth Scenarios.** For Tests sub8_04 through sub8_07, where the boat was initially at periscope depth and rose to the surface, a 5 minute minimum delay in commencing ventilation was used. This delay represented the approximate time required for personnel to align valves and dampers, set ballast tanks, and for the boat to ascend and stabilize at the proper depth, before ventilation could commence. Commencement of ventilation was left to the discretion of the Casualty Coordinator.

- **Rapid Response Team and Hose Teams.** For Tests sub8_01 and sub8_02, personnel protection gear was stowed in normal locations and test personnel were staged in the CPO/Crew Mess. The Rapid Response Team and the Hose Team were free to respond without any constraints. After Test sub8_02, personnel

protection equipment was staged in the CPO/Crew Mess and personnel partially donned their protection equipment before the fire was ignited. To provide realistic response times after Test sub8_02, the Rapid Response Team and the Hose Teams were delayed approximately three and six minutes, respectively, after the fire was announced. Test participants were allowed to use their breathing apparatus at any time when they felt breathing protection was needed.

11.3 Protective Equipment

The levels of protective equipment were a factor in the effectiveness of the fire fighting response. The personnel protection equipment used by test participants was in accordance with standard Fleet practice for responding to a fire aboard a submarine. The personnel protection equipment worn by an individual was determined by that individual's pre-assigned duties and was not adjusted based on the severity of the fire or the fire fighting environment. Appendix C also provides a log of the protective gear each test participant wore during each fire scenario. The level of protection can be defined by three levels, each having an increased degree of protection above the previous level:

1. Watchstander Protection – Clothing normally worn by submarine Watchstanders. This included long sleeved coveralls or long sleeved cotton shirts and dungarees, along with high topped boots. In all tests, SCBAs or OBAs were worn for safety reasons. Watchstander initially responded with an SCBA or OBA on, but the face piece was not donned. When relieved or forced out by the heat and smoke, the Watchstander returned to the CPO/Crew Mess, donned the face piece and attached the rope tether to simulate using an EAB mask.

2. Rapid Response Teams Protection – This represents an increase in the level of protection over standard Watchstander clothing and is equipment which can be quickly donned, e.g., while moving toward the scene of a fire. In addition to Watchstander clothing, a flashhood and cotton flash gloves were provided and simulated EABs were worn. The result was all exposed skin surfaces were covered. SCBAs and OBAs were used in lieu of EABs in this test series. Participants donned the SCBA or OBA prior to the test, but did not don the face piece. When the fire was called away, the participants donned the face piece and hooked their tethers into one of the simulated EAB manifolds. Participants agreed that the time to don the simulated EAB (SCBA or OBA) face piece and hook into the EAB manifold was similar to the time required to don an actual EAB. The time to remove the EAB mask from the storage container was neglected.

3. Hose Team Protection – The nozzleman and NFTI operators donned the one-piece Nomex FFE, two flashhoods, and fire fighters gloves and used OBAs. Hosemen and plugmen wore the same protection as the Rapid Response Team except they had on OBAs instead of EABs.

11.4 Personnel Response

Test participants followed the standard Fleet procedure for responding to a fire for all of the tests, specifically:

1. The Watchstander discovered the fire, reported it to the Casualty Coordinator and attacked it with the nearest appropriate portable extinguisher. For most fires, a portable CO_2 extinguisher was used. Depending on the fire conditions, the Watchstander continued to attack the fire until forced out by the heat and smoke or when relieved by the Rapid Response Team. When the Rapid Response Team arrived the Watchstander either remained on the scene to assist or returned to the CPO/Crew Mess. The Watchstander used an EAB (simulated by an OBA with a tether) if breathing protection was needed.

2. The Rapid Response Team (three people) arrived on scene with portable extinguishers, assisted or relieved the Watchstander, and attacked the fire. Typically, one of the team members attacked the fire, the second team member supplied portable extinguishers and the third team member started to rig a 3.8-cm (1.5-in.) hose.

3. The Man-in-Charge (typically the XO) arrived on scene from the Control Room/DC Central to direct the fire fighting efforts.

4. The Hose Teams (two teams of four people each) arrived on scene and reported to the Man-in-Charge. The Hose Teams were directed to stand by, to attack the fire, or the Man-in-Charge assigned actions to specific personnel, such as the NFTI operator, as required.

As personnel arrived on scene, the Man-in-Charge assigned tasks to personnel to accomplish the most effective attack on the fire, whether or not such actions were consistent with the pre-planned, standard response.

11.5 Tactics and Techniques

Tactics and techniques used in fire fighting may impact on the overall effectiveness of a fire fighting strategy (strategy here may be defined in terms of the level of personnel protection and the sequence of use of equipment). An optimum response to a given threat in terms of manpower, personnel protection, and fire fighting equipment selection may be affected by the tactics and techniques used by the individual fire fighters. In this test series, the test personnel were free to attack the fire without any previous direction from the test team. The attack and progression of fire fighting utilized was as taught and described in the NSTM Chapter 555, Volume 2 [3]. One change emphasized after the Test sub8_01 was the judicious use of CO_2 extinguishers. Due to the limited number of CO_2 extinguishers available for testing, the trained

response of discharging two CO_2 extinguishers on the fire during the initial attack was discouraged. The test personnel were also told during the pre-test brief what type of fire to expect, which allowed them time to decide which type of portable extinguisher to use and plan where to retrieve that portable.

The vari-nozzles on the 3.8-cm (1.5-in.) diameter hose lines were initially set to provide a 30° fog pattern. The use of the fog pattern or changing to a straight stream or a wider fog pattern was left to the discretion of the nozzleman. The effectiveness of the spray pattern was discussed in the post-test debrief. The application of water continuously or in short water bursts was also left to the discretion of the nozzleman. The effectiveness of the short water burst technique has been shown in Navy fire fighting tests involving electrical cables [15] and previous manned submarine testing [16].

The 1.9-cm (0.75-in.) diameter hose reel system was intended to provide supplemental capability to portable extinguishers and the 3.8-cm (1.5-in.) diameter hose lines. To evaluate this, in Test sub8_07, the test participants were instructed to use the hose reels as supplemental fire fighting equipment. This allowed for feedback from the personnel on the effectiveness and ease of use of the hose reel and allowed the guidance of their use against different threat levels to be incorporated into existing doctrine, tactics and procedures.

11.6 Post-Test Debriefing

Immediately following each fire test, the fire fighting participants were debriefed. The discussion was lead by the test director who was stationed in the SHADWELL Test Control Center during each test. The debriefing was conducted before clean-up and the participants were cautioned against discussing the results until after the debriefing. All debrief sessions were video taped to have a permanent record of all factual and anecdotal information provided by the participants.

12.0 VENTILATION SYSTEM ALIGNMENTS

Various ventilation system alignments were evaluated to simulate the modes currently used on the 688 Class submarine, as well as proposed modes for desmoking. The SHADWELL/688 ventilation system is intended to represent an 83 percent scaling factor to actual submarine fan capacities and airflow rates. This scaling factor accounts for the reduced volume of the test space in relation to the submarine. Two ventilation modes were used for removing smoke from the test space: Emergency ventilate mode and the Control Room Sweep. Emergency ventilate mode is the use of the ventilation system to remove smoke and heat *after* the fire is out. This is the current standard emergency ventilation mode used onboard submarines. The Control Room Sweep is the use of the ventilation system to remove smoke and heat from the Control Room *before* the fire is out.

After the fire was out, the Control Room Sweep was augmented by running the supply and induction fans to desmoke the forward compartment. In previous testing [8,9], frame bay smoke stops were shown to be a very effective method for limiting vertical smoke spread. This design concept was not evaluated during this test series, but should be considered in future submarine designs.

The three main ventilation system alignments used in this test series were as follows:

1. Emergency Ventilate Mode - While at periscope depth (or at the surface where the bridge hatch cannot be opened) the ventilation system can be aligned to operate in "Emergency Ventilate Mode." NSTM Chapter 555 - Volume 2, Section 555-32.2.1, Ventilation Modes, [3] describes the emergency ventilate mode as "...the ventilation means used for the evacuation of a specific compartment or compartments of atmospheric contaminates such as smoke, toxic gas or other objectionable gases. In this open loop mode, a supply of fresh air is brought into the ship through the snorkel induction system [induction fans operating at slow speed] while air from the contaminated space is exhausted overboard using either the diesel generator or the L.P. blower." The SHADWELL/688 ventilation does not have a dedicated induction system. Rather, the exhaust fan was used to draw in air from weather at 2.1 m^3/sec (4500 cfm). An isolation valve was used to isolate the exhaust fan from the test area exhaust ducting, and the induction valve was opened to connect the fan inlet to the outside through an opening in the sail. In this configuration, the exhaust fan was effectively used as the induction fan. The dedicated L.P. blower fan was started at 0.7 m^3/sec (1500 cfm) exhausting air from a selectable terminal from either the NAV Equipment Room or AMR.

2. Control Room Sweep - This is the ventilation mode proposed for active desmoking, that is, desmoking before the fire is out to maintain Control Room tenability. While at the surface, the bridge hatch (H1), as shown in Figure 2, was opened, as was the NAV Equipment Room door. The L.P. blower fan was started at 0.7 m^3/sec (1500 cfm) exhausting air from the NAV Equipment Room terminal. The objective was to draw fresh air in through the bridge hatch, through the Control Room, and out through the emergency ventilation terminal in the NAV Equipment Room, thereby improving tenability conditions in the Control Room.

3. Supply Fan/Control Room Sweep - This ventilation alignment was devised and evaluated during the Phase I tests and shows promise as an easily implemented means of effective post-fire desmoking after a Control Room Sweep is operating. While continuing the Control Room Sweep, as described above, the supply fan is operated at its normal recirculation mode flow rate of 3.0 m^3 /sec (6300 cfm). This caused a negative pressure in the Fan Room, drawing more fresh air in through the open induction system (operating the induction fans increased the fresh air flow further). This air was distributed throughout the forward

compartment, improving the effectiveness of post-fire desmoking. During Tests sub8_04, sub8_06 and sub8_07, exhaust was through the NAV Equipment Room terminal. During Test sub8_05, exhaust was through the AMR terminal. During Test sub8_04, only the supply fan was used to augment the Control Room Sweep. During Tests sub8_05, sub8_06 and sub8_07, both the supply and induction fans were used to augment the Control Room Sweep.

Active desmoking was conducted during Test sub8_04. While fire fighting operations were continuing, the L.P. blower was started as the bridge hatch was opened. As soon as the fire was reported out, the supply fan was started. The combination of the supply fan and the L.P. blower (exhausting from AMR) operating and the bridge hatch open noticeably improved the Control Room/DC Central tenability conditions. Heat and smoke conditions on the lower platforms immediately began to improve as reported by the Man-in-Charge.

13.0 TEST RESULTS

Results of the testing are summarized in Tables 2 and 3. Table 2 summarizes the test scenarios, objectives, test-specific procedures, ventilation alignment and general comments for all of the tests performed. Table 3 summarizes key data from all seven tests. Values in Table 3 are given for:

- temperatures once fire fighting was initiated (approximate);
- visibility once fire fighting was initiated (approximate);
- fire(s) reported out;
- initiation of active ventilation; and
- 10 minute period following initiation of active ventilation.

Values for Test sub8_04, where active desmoking was conducted, were the same as for other tests, except the last key event was the 10 minute period following the report of fire out. The time each event occurred is also shown with the appropriate data. The results of each test, including a narrative of events as gathered from the debriefings and the instrumentation, are discussed independently. The results are also summarized in Section 13.9 Ventilation Alignment Results. Detailed summary data sheets for each test are contained in Appendix E. One objective of the test series was to evaluate the effectiveness of the Control Room Sweep for active desmoking, that is, desmoking before the fire is out. However, due to the rapid extinguishment of the fires by the test participants, Test sub8_04 was the only test in which the Control Room Sweep commenced before the fire was extinguished. Representative data, graphically showing visibility, temperature and pressure for each compartment, are contained in Appendix F.

Table 2. Manual Intervention Fire Scenarios, Ventilation Alignments and General Results

Test No.	Fire	Fuel Package	Ventilation Alignment (SHADWELL) [1]	Objective	Test-Specific procedures	Comments
sub8_01	Laundry	Class A wood crib	**Current Emergency Ventilate mode (a)**: SHADWELL exhaust fan aligned as induction; L.P. blower exhausting out of AMR.	Baseline fire scenario; easy access to fuel package, use existing ventilation doctrine.	Minimum 10 min delay in starting ventilation simulating time to periscope depth; immediate response by test personnel.	CO_2 extinguishers effective in extinguishing fire; Ventilation alignment did not improve overall tenability conditions.
sub8_02	AMR	Class A wood crib	**Current Emergency Ventilate mode (a)**: SHADWELL exhaust fan aligned as induction; L.P. blower exhausting out of AMR.	Baseline/harder fire scenario; more difficult access to fire; use existing ventilation doctrine.	Minimum 10 min delay in starting ventilation simulating time to periscope depth; immediate response by test personnel.	PKP extinguisher very effective in extinguishing fire; ventilation alignment slightly improved overall tenability conditions.
sub8_03	Laundry & AMR	Class A wood crib	**Modified Emergency Ventilate Mode (a)**: SHADWELL exhaust fan aligned as induction; L.P. blower exhausting out of AMR; supply fan operating.	More challenging fire scenario, multiple fire sources, evaluate use of supply fan in improving tenability conditions.	Minimum 10 min delay in starting ventilation simulating time to periscope depth; delayed response of test personnel.	Fire did not require surfacing of the boat; supply fan improved conditions on third platform; AMR fire reflashed and difficult to extinguish.
sub8_04	AMR	Class A wood crib and 0.51-m Class B diesel pan fire	**Active Desmoking; Control Room Sweep (b)**; H1 open; L.P. blower exhausting out of NAV Equip; supply fan operated for post-fire desmoking.	Multiple fire sources; multiple fire types.	Minimum 5 min delay in starting ventilation simulating time to surface; delayed response of test personnel.	Control Room Sweep quickly improved Control Room/DC Central tenability. Supply fan improved overall tenability conditions quickly.

[1] Letters in parentheses indicate the comprehensive text description for the ventilation alignment found in Section 7

Table 2. Manual Intervention Fire Scenarios, Ventilation Alignments and General Results (Cont.)

Test No.	Fire	Fuel Package	Ventilation Alignment (SHADWELL)	Objective	Test-Specific procedures	Comments
sub8_05	AMR	Class A wood crib and 0.51-m Class B diesel pan fire	**Supply Fan/Control Room Sweep (c)**: H1 open; L.P. blower exhausting out of NAV Equip, and supply fan operating; 1 min delay in operating induction fan.	Evaluate effect of varying ventilation sequencing, compare results with Test sub8_04. Use Supply Fan/Control Room Sweep ventilation alignment.	Minimum 5 min delay in starting ventilation simulating time to surface; delayed response of test personnel.	Supply fan quickly improved tenability conditions throughout boat; induction fan did not adversely affect overall tenability; switched L.P. blower terminal during test to AMR, improved smoke and heat immediately.
sub8_06	Laundry & Wardroom	Class A wood crib and wooden framebay	**Supply Fan/Control Room Sweep (c)**: H1 open and L.P. blower exhausting out of NAV Equip; 1 min delay in starting supply fan; 1 min delay in operating induction fan.	Challenging multi-deck fire; use modified Supply Fan/Control Room Sweep ventilation alignment.	Minimum 5 min delay in starting ventilation simulating time to surface; delayed response of test personnel; access to Laundry fire delayed due to locked door.	Fire was not fully developed prior to suppression; locked Laundry door delayed response to cabinet fire; Control Room/DC Central tenability conditions improved.
sub8_07	Laundry, AMR & Wardroom	Class A wood crib, wooden framebay, and 0.51-m diesel pan fire	**Supply Fan/Control Room Sweep (c)**: H1 open and L.P. blower exhausting out of NAV Equip; 1 min delay in starting supply fan; 1 min delay in operating induction fan.	Challenging multi-deck, multi-type scenario; use modified Supply fan/Control Room sweep ventilation alignment; evaluate 0.75-in. hose reels.	Minimum 5 min delay in starting ventilation simulating time to surface; delayed response of test personnel; 0.75-in. hose reels used.	Framebay and Class B fire did not ignite; 0.75-in. hose reels provided quick extinguishment; Control Room/DC Central tenability conditions improved.

Table 3. Control Room/DC Central Tenability Conditions Results

Test No.	Scenario	Fire Fighting Initiated			Fire(s) Reported Out [Fire Out]			Initiation of Ventilation [Vent]			Ventilation + 10 minutes [Vent+10]		
		Time (min:sec)	Min. Vis. (%)	Max. Temp. (°C)	Time (min:sec)	Vis. (%)	Temp. (°C)	Time (min:sec)	Vis. (%)	Temp. (°C)	Time (min:sec)	Vis. (%)	Temp. (°C)
sub8_01	Class A Fire in Laundry	3:00	6	62	7:17	29	46	11:37	49	42	21:37	73	42
sub8_02	Class A Fire in AMR	3:30	1	65	15:37	3	44	19:52	7	40	29:52	50	38
sub8_03	Class A Fire in AMR and Laundry	3:30	0	63	20:02	0	51	23:24	0	55	33:00	10	54
sub8_04*	Class A & B in AMR	5:00	0	58	19:35	88	27	13:17	5	55	29:35	92	28
sub8_05	Class A & B in AMR	3:45	3	48	10:20	7	45	12:47	17	42	22:47	94	35
sub8_06	Multi-level Class A in Laundry and Wardroom	6:30	0	147	14:50	25	51	15:17	26	51	25:17	83	37
sub8_07	Fires 01, 04 and 06	3:30	1	75	9:24	1	57	10:44	2	61	20:44	72	53

Note: 1. Visibility and Temperature values shown at 1.5-m (5-ft) height above deck.

* Test sub8_04 evaluated Active desmoking. Column labeled "Ventilation + 10 minutes [Vent+10]" is actually "Fire Out + 10 minutes [Fire Out + 10]

13.1 Measures of Performance

The primary measures of performance for test evaluations were smoke filling time and compartment temperature. When these parameters exceed a threshold value, the ability of personnel to perform their assigned tasks (e.g., fire fighting, operating submarine controls, standing watch) would be limited. Reduced visibility due from smoke filling the compartment prevents personnel from operating ship controls. Excessive compartment temperatures result in burns to exposed skin and eventual incapacitation. For tenability conditions, a minimum transmittance of 10 percent as measured by the ODMs and a maximum temperature of 48°C (118°F) over a 180 second time period as measured by a thermocouple (TC) at the 1.5-m (5-ft) height were used. The 1.5-m (5-ft) height represents head height of an average adult standing in a compartment.

When visibility is reduced below 3 m (9.8 ft) along an escape route, personnel will generally turn around and seek out another route [17]. It is realized that a submarine's crew is highly trained and familiar with their surroundings. They may remain at their stations with the assistance of EAB protection. However, as visibility decreases, it would become very difficult for crew members to function and operate the submarine. For the purposes of comparisons associated with these tests, a threshold value of 10% transmittance was used. A 10% transmittance value equates to a visibility distance on the order of 1.0 to 2.0-m (3.3 to 6.6-ft) [18, 19]. On graphs for each test showing the percent transmittance as a function of time, a "minimum visibility" line of 10% is included. This represents the minimum visibility necessary for personnel to operate a submarine. The Casualty Coordinator, stationed in the Control Room/DC Central for Tests 1 through 6, stated that when the visibility as measured by the ODM 1.5-m (5-ft) above the deck was 10%, he could see the red LED temperature readout from a distance of approximately 1.2-m (4-ft). When the ODMs measured 0% visibility, the Casualty Coordinator stated he could see the red LED temperature readout up close. This indicates that the minimum visibility value of 10% is conservative, but realistic.

When the temperature in a compartment exceeds 48°C (118°F) over a 180 second time period, the pain threshold of exposed skin is exceeded resulting in thermal burns [20]. At elevated temperatures, personnel are forced to cover all exposed skin, which makes performing duties difficult. On graphs for each test showing the compartment temperature as a function of time, a "pain threshold" line of 48°C (118°F) is included. Representative measure of performance data for all seven tests is contained in Appendix H.

13.2 Test sub8_01

The first test was a baseline/warm-up test to acquaint the test participants with the test space, test procedure and use of fire fighting equipment. A Class A wood crib was located in the forward end of the Laundry Fire Compartment. Metal lockers were staged in the fire

compartment to prevent direct access to the fire. This forced the fire fighters to maneuver around the obstructions to reach the seat of the fire. Initially the boat was submerged. After the fire was called away, the boat proceeded to periscope depth. A 10 minute delay (simulating the time required to align the proper valves, dampers, fans, etc.,) was introduced from the time the fire was called away until initiation of mechanical ventilation (emergency ventilation mode) could begin. This time also included the time necessary to rise from depth to periscope depth and raise the snorkel induction mast.

Approximately 23 seconds after ignition, the Casualty Coordinator reported heavy smoke filling the Control Room/DC Central. It took the Watchstander 1 minute, 37 seconds to discover the fire and make the report to the Control Room/DC Central. The Watchstander reported that he returned to the fire with a CO_2 extinguisher. The extinguisher was discharged and the visible flames knocked down. This was noticed in the Control Room/DC Central where the ODMs measured a temporary improvement in visibility from 18% to 34%. The maximum temperatures measured in the forward end of the Laundry Fire Compartment prior to initiation of fire fighting was 355°C (671°F).

As the fire re-established itself, the visibility in the Control Room/DC Central began to decrease. Three minutes after the fire was ignited, the first hose was being rigged by the Rapid Response Team. Concurrently, a second and third CO_2 extinguisher were brought into the fire compartment and discharged. No visible flames were reported by the Man-in-Charge 2 minutes, 35 seconds after the fire was called away. The temperature in the Control Room/DC Central reached a maximum of 62°C (145°F) at this time. The visibility in the Control Room/DC Central also reached a minimum of 6% around this time. The Rapid Responders and the Man-in-Charge later reported heavy smoke and poor visibility in the vicinity of the fire compartment.

The fire was reported out by the Man-in-Charge at 7 minutes, 17 seconds (5 minutes, 40 seconds after the fire was called away). A total of 265 ℓ (70 gal) of water was used during the test. Tenability conditions began to improve slightly in the Control Room/DC Central. The temperatures in the Control Room/DC Central began to steadily drop after extinguishment, to about 48°C (118°F). During the period between the fire being reported out and the commencement of emergency ventilation, the visibility in the Control Room/DC Central improved at a rate of 4.6 %/min (from 29% to 42%) and temperatures decreased at a rate of 0.9 °C/min (from 46°C (115°F) to 42°C (108°F)). Eleven minutes, 37 seconds after ignition (10 minutes after the fire was called away), the Control Room/DC Central was informed that the boat was at periscope depth and emergency ventilation commenced. The exhaust fan, aligned as the induction fan, was started and the L.P. blower exhausted air from AMR. During the 10 minute period following the commencement of emergency ventilation, the visibility in the Control Room/DC Central improved at a rate of 2.4 %/min, 49% to 73%. The Control Room/DC Central temperatures remained relatively constant during this period at approximately 42°C (108°F). Fire fighters on the third platform later reported the ventilation alignment did little to improve the heat and smoke conditions near the fire area. Twenty-eight minutes, 13 seconds after the fire was

ignited, the test was secured as conditions were not improving on the second and third platforms. The Control Room/DC Central visibility, as measured by the two ODMs, is shown in Figure 28. The effect of the ventilation scenario and the fire fighting on Control Room temperatures is shown in Figure 29. The timeline of key events for Test sub8_01 can be found in Appendix H.

13.3 Test sub8_02

The second test was a baseline/warmup test with a Class A wood crib located in the AMR. Access to the fire was more difficult with the fuel package located within Obstruction 3. Initially the boat was submerged. After the fire was called away, the boat proceeded to periscope depth. A 10 minute delay was introduced from the time the fire was called away until initiation of mechanical ventilation (emergency ventilation mode) could begin. The ventilation alignment was the same as Test sub8_01, standard emergency ventilate mode.

The fire was called away by the Control Room/DC Central 2 minutes, 55 seconds after ignition. The visibility in the Control Room/DC Central was approximately 90%, but dropped to 35% over the next minute. The Man-in-Charge and the Casualty Coordinator reported that smoke filled the Control Room/DC Central much slower than in Test sub8_01. After informing the Control Room/DC Central of the fire, the smoke was heavy enough to force the Watchstander to don breathing air for safety reasons. He then retrieved a PKP extinguisher from Torpedo Room aft and returned toward AMR. The PKP extinguisher was passed to the Rapid Response Team and the Watchstander returned to CPO/Crew Mess. The first Rapid Responder initially grabbed the AFFF extinguisher located at the top of the ladder going down into the Laundry space. He entered the AMR and expended the AFFF on the visible flames, knocking down the fire. The temperatures in the Control Room/DC Central peaked at 65°C (149°F) at this time. The second arriving Rapid Responder took the PKP extinguisher brought to the scene by the Watchstander and quickly knocked down the remaining visible fire. Once the PKP was empty, a water extinguisher (simulating an AFFF extinguisher), brought to the scene by the second Rapid Responder, was used. It did very little to extinguish the fire. As the second Rapid Responder emptied the water extinguisher, the 3.8-cm (1.5-in.) diameter hose line was rigged from the torpedo room aft plug 7 minutes, 47 seconds after the fire was called away. The second Rapid Responder applied short bursts of water onto the fire until the nozzleman in an FFE arrived.

As water was being applied to the fire using the primary hose line, the visibility in the Control Room/DC Central dropped to 1%. The temperatures in the Control Room/DC Central were approximately 50°C (122°F) but dropped quickly as the fire was knocked down and extinguished. The Man-in-Charge directed the second hose team to bring the second platform passageway hose line aft into CPO/Crew Mess and down through the scuttle into AMR. Fifteen minutes, 37 seconds after the fire was ignited (12 minutes, 42 seconds after the fire was called away) the fire was reported out by the Man-in-Charge and hot spots were being cooled. A total

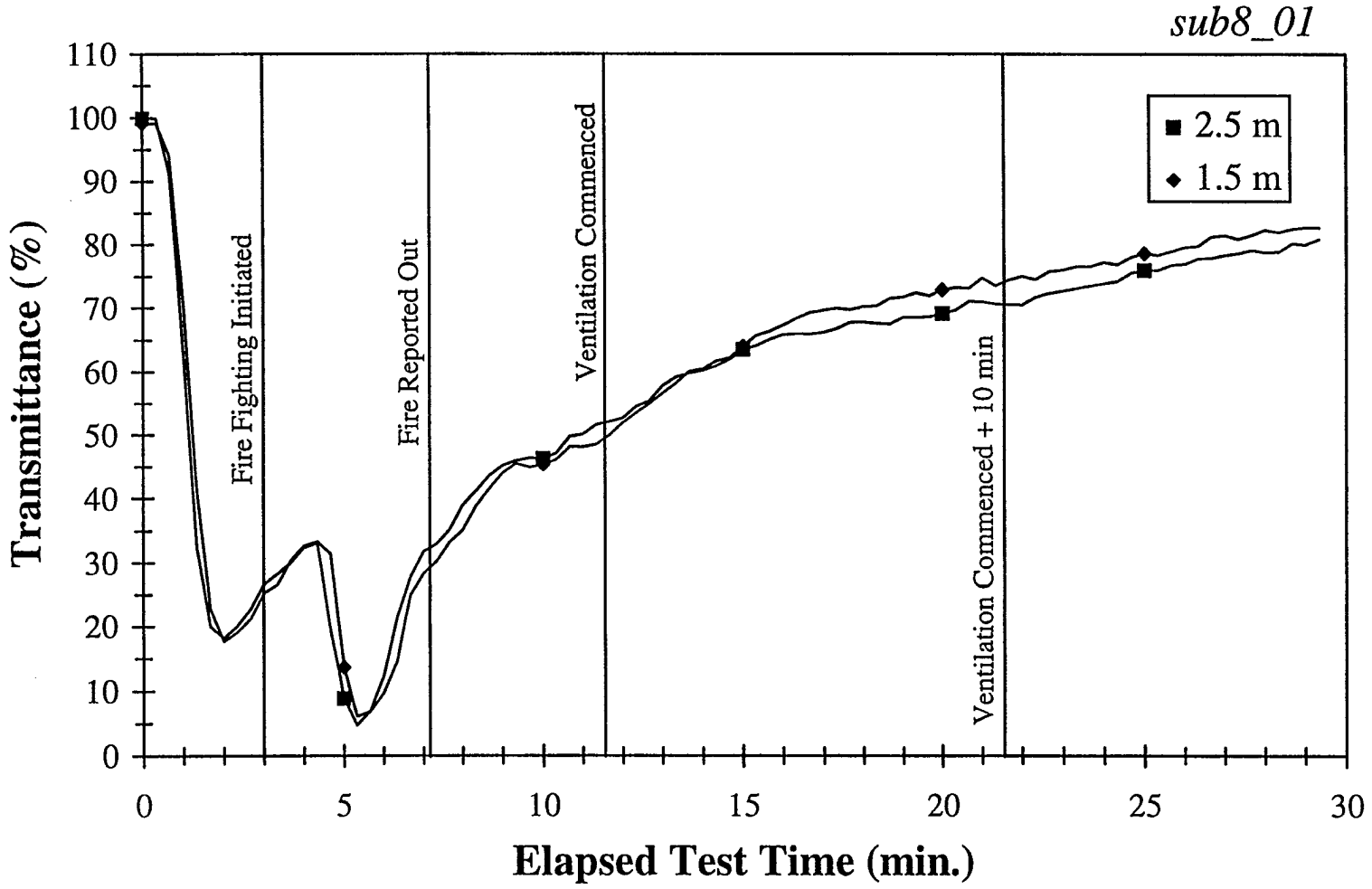


Fig. 28 – Control/DC Central visibility, Test sub8_01

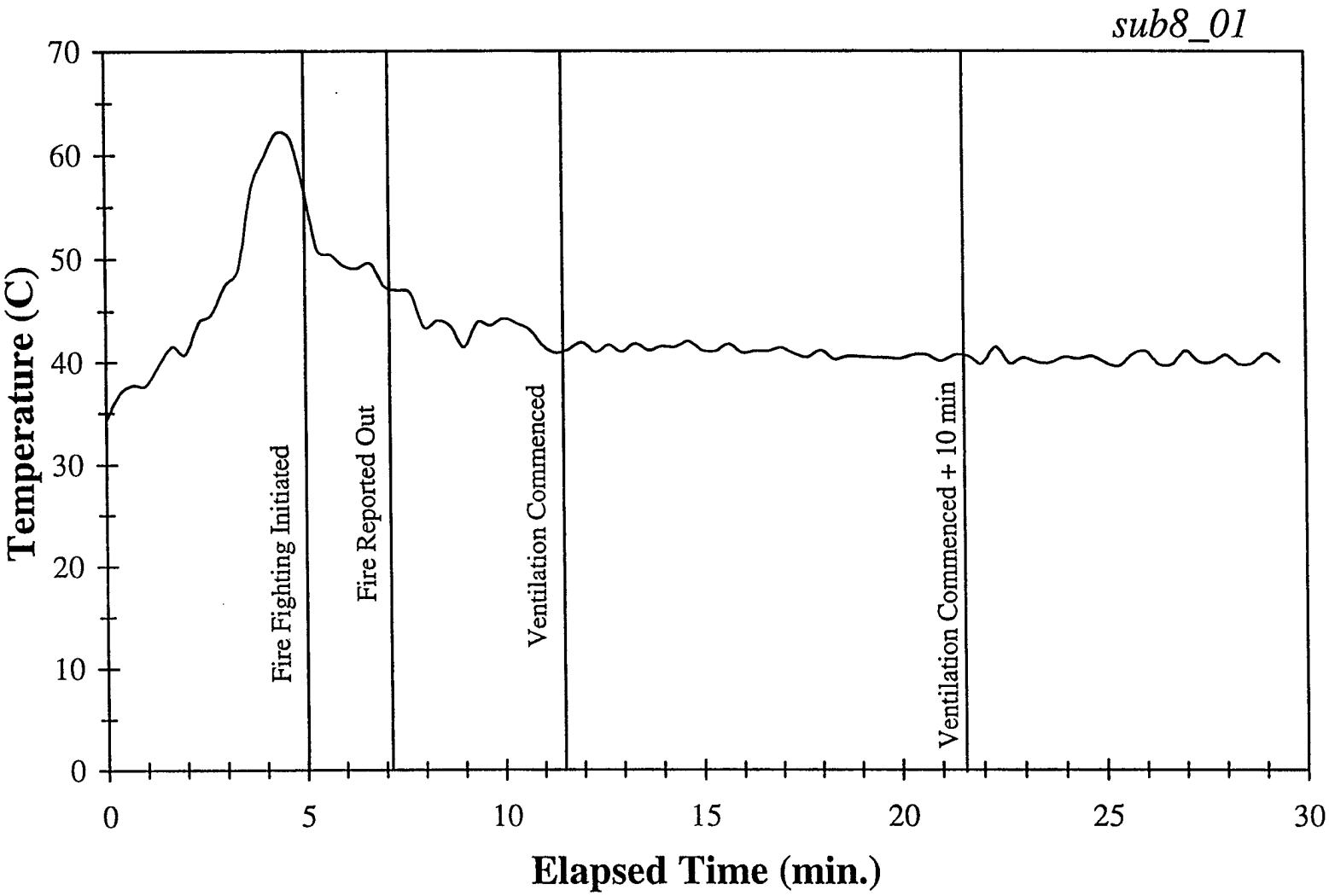


Fig. 29 – Control Room/DC Central temperatures, Test sub8_01

of 2,555 ℓ (675 gal) of water was used during the test. Having previously beeen informed that the boat was at periscope depth, the Control Room/DC Central ordered commencement of emergency ventilation as the fire was reported out. Emergency ventilate commenced at 19 minutes 52 seconds after the fire was ignited. During the time between the fire being reported out and the commencement of emergency ventilation, there was little improvement in the Control Room/DC Central tenability conditions. The visibility improved at a rate of 0.9 %/min, from 3% to 7%, and temperatures at a rate of 0.9°C/min, from 44°C (111°F) to 40°C (104°F). The exhaust fan, aligned as the induction fan, was started and the L.P. blower exhausted air from AMR. In CPO/Crew Mess, the visibility was 49% as active ventilation was started. The visibility dropped to 44% over the next two minutes, then began to increase to 83% at the end of the test. During the 10 minute period after ventilation commenced, visibility in the Control Room/DC Central improved at a rate of 4.3 %/min (7% to 50%) and the temperatures decreased at a rate of 0.2°C/min (2°C (4°F) during this period). Fire fighters on the third platform later reported the ventilation alignment again did little to improve the heat and smoke conditions near the fire area. Thirty-three minutes, 52 seconds after the fire was ignited, the test was secured as conditions did not improve on the second and third platforms. The visibility as measured by the two ODMs in the Control Room/DC Central is shown in Figure 30. The effect of ventilation and fire fighting on the Control Room/DC Central temperatures is shown in Figure 31. Figure 32 shows a comparison of the visibility in the Control Room/DC Central for Tests sub8_01 and sub8_02 at the 1.5-m (5-ft) high ODM. A comparison of the temperatures at 1.5-m (5-ft) off the deck for both tests is shown in Figure 33. Data for Test sub8_03 are also included in Figures 32 and 33 and will be discussed below. The timeline of key events for Test sub8_02 can be found in Appendix H.

13.4 Test sub8_03

The third test involved a Class A wood crib located in the forward end of the Laundry Fire Compartment and a second Class A wood crib located within Obstruction 3. Initially the boat was submerged. After the fire was called away, the boat proceeded to periscope depth. A 10 minute delay was introduced from the time the fire was called away until initiation of mechanical ventilation(emergency ventilation mode). The ventilation alignment was modified for this test. Upon commencing emergency ventilation, the current emergency ventilation alignment was to be used (induction fan and L.P. blower operating) with the supply fan operating at recirculation mode capacity (3.0 m^3/sec (6300 cfm)). Based on previous testing, [4], the supply fan would circulate the air throughout the boat, reducing the heat and smoke load in the lower platforms to assist the fire fighters, without significantly increasing the fire size or deteriorating Control Room tenability conditions.

The Control Room/DC Central called away the fire in Laundry 2 minutes, 12 seconds after the fires were ignited. The Watchstander reported that as he discovered the fire, the smoke was heavy enough to force him to don his SCBA for safety reasons. He retreated forward to the Torpedo Room where he grabbed the PKP extinguisher located in Torpedo aft and returned to the Laundry Fire Compartment. He attempted to discharge the extinguisher from the aft end of the Laundry compartment, but the nozzle clogged. At that time he backed out and the Rapid Response

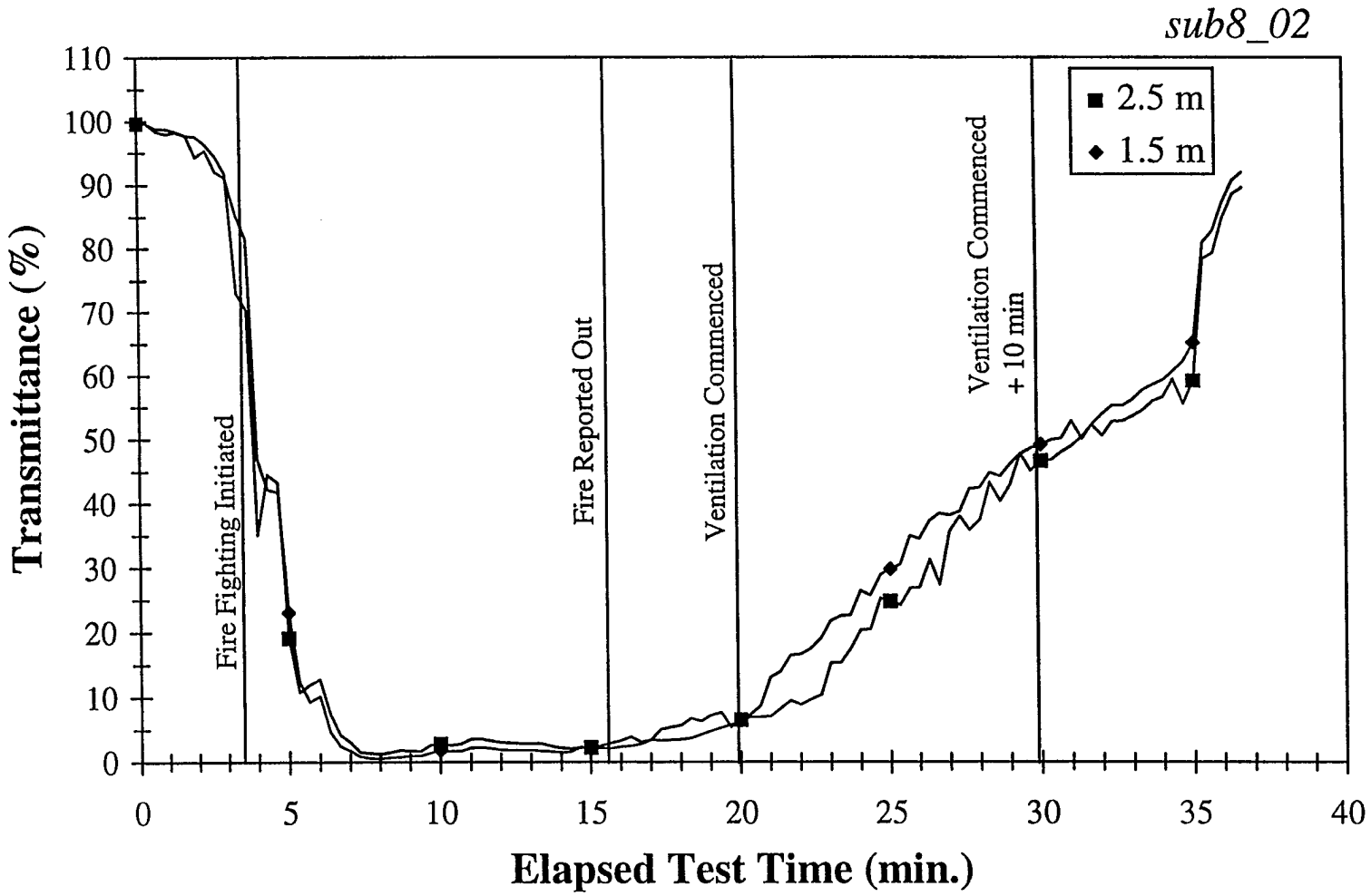


Fig. 30 – Control Room/DC Central visibility, Test sub8_02

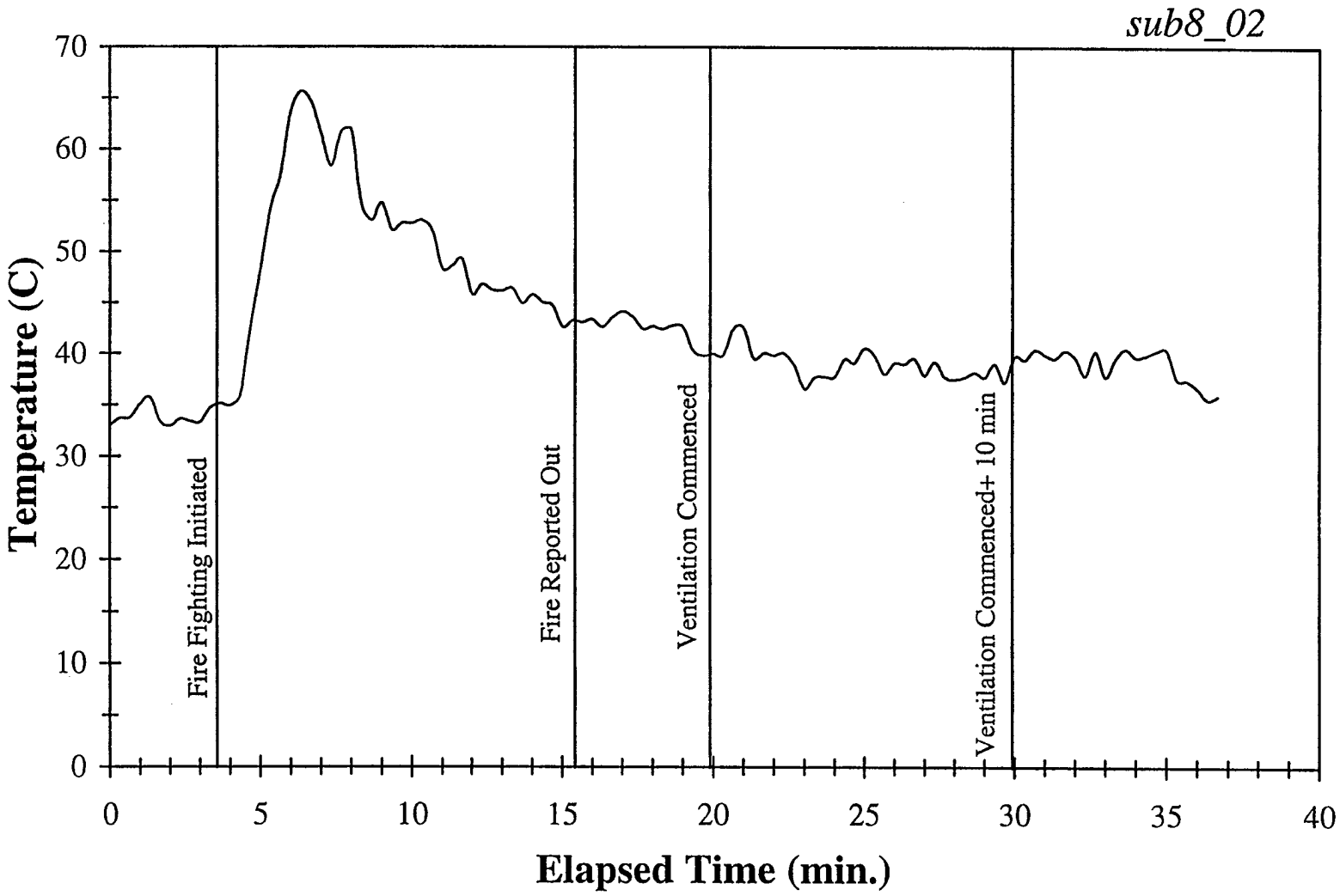


Fig. 31 – Control Room/DC Central temperature, Test sub8_02

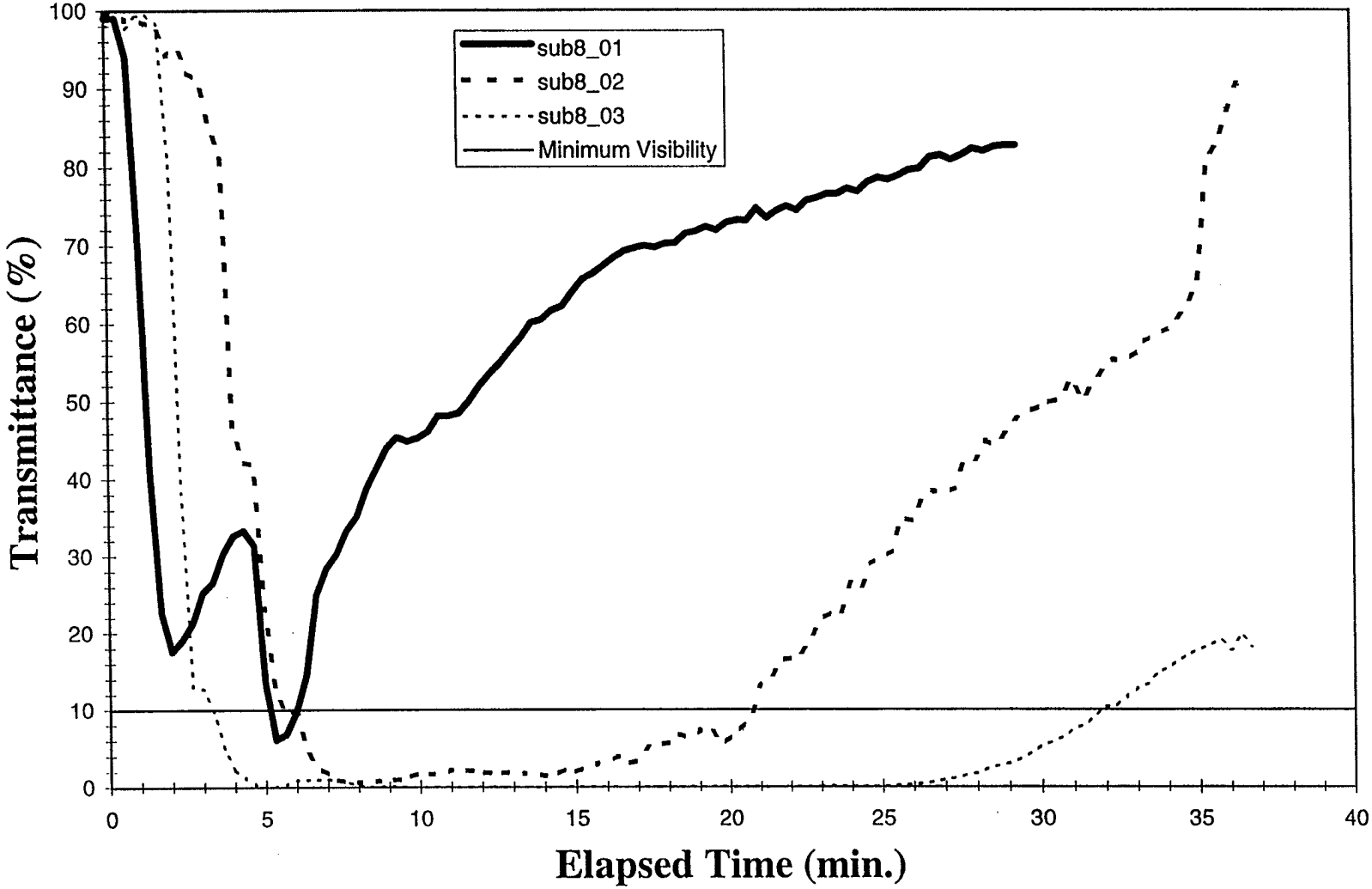


Fig. 32 – Control Room/DC Central visibility (1.5 m ODMs), Test sub8_01, _02, and _03

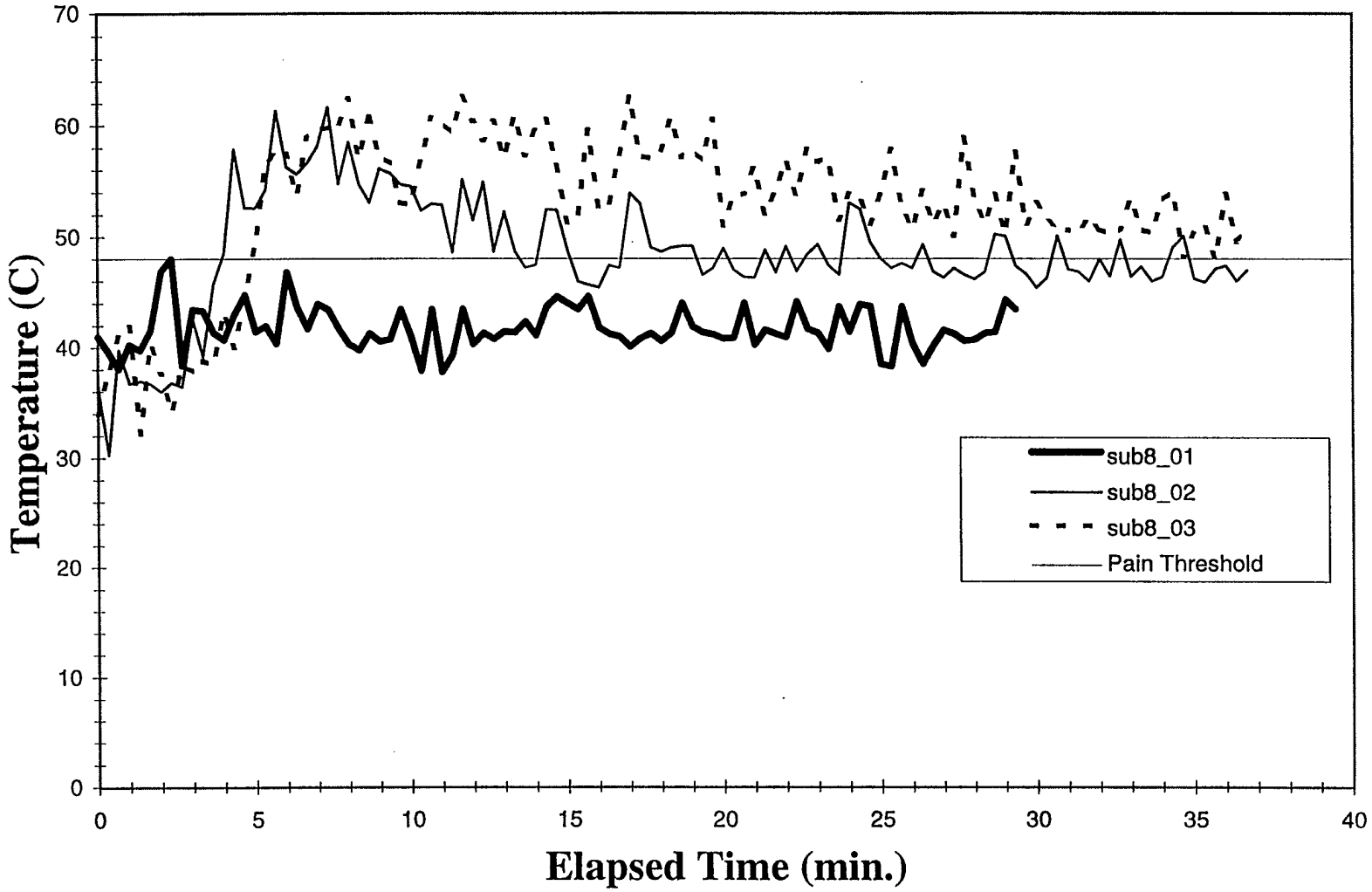


Fig. 33 – Control Room/DC Central temperatures (1.5 m TCs), Test sub8_01, _02, and _03

team arrived on scene. The Watchstander retrieved the AFFF extinguisher at the bottom of the ladder in Laundry from the second platform and brought it to the Rapid Response team. The Watchstander then proceeded to investigate the AMR and discovered the fire in AMR. The Control Room/DC Central called away the fire in AMR 4 minutes, 34 seconds after the fires were ignited. As the fire was called away in AMR, the visibility in the Control Room/DC Central approached 0%. Two minutes later, the temperature in the Control Room/DC Central peaked at 63°C (145°F).

The first Rapid Responder used the AFFF extinguisher provided by the Watchstander to attempt to extinguish the fire in Laundry. The AFFF did nothing to suppress the fire and was expended. A second PKP extinguisher was brought into the Laundry Fire Compartment and the visible flames were extinguished, 5 minutes after the fires were ignited. As the PKP was used to control the fire in the Laundry, the temperatures in the Laundry Fire Compartment dropped from a maximum of 295°C (563°F) to 50°C (122°F) in less than 2 minutes. The 3.8-cm (1.5-in.) diameter hose line from the Torpedo Room aft plug was rigged into the Laundry Fire Compartment as the primary hose by the Watchstander. The second Rapid Responder went to the AMR with a PKP extinguisher. The PKP extinguisher was discharged, knocking down the visible flames. The third Rapid Responder rigged the hose from the second platform passageway plug, down the ladder into Laundry, and aft into AMR. This became the secondary hose. When the hose was being brought down the ladder, the line was charged, resulting in a number of kinks. This slowed the response as the fire fighters had to straighten the line before adequate water pressure was available at the nozzle. At 7 minutes, 57 seconds after the fire in Laundry was called away, the Laundry fire was reported out. The AMR fire was also reported out at the same time (6 minutes, 35 seconds after the fire in AMR was called away). Fifty-five seconds later, the fire in AMR reflashed. The fire was fought with the secondary hose line until it was reported out 17 minutes, 40 seconds after the fire was called away. A total of 2,449 ℓ (647 gal) of water was used during the test.

Once the fires were reported out, "Commencing Emergency Ventilate" was called by the Control Room/DC Central over the 1MC, 23 minutes, 24 seconds after the Laundry fire was called away. During the period between when the fires were reported out and emergency ventilation commenced, there was no recovery of visibility and the temperatures in the Control Room/DC Central increased at a rate of 1.2°C/min. Upon commencement of emergency ventilation, the exhaust fan was aligned as induction and started, the supply fan was started and the L.P. blower exhausted air from AMR. The visibility in the Control Room/DC Central was initially 0% and slowly improved to 10% over the next ten minutes, a recovery rate of 1 %/min. The ventilation alignment showed no added effect in decreasing the Control Room/DC Central temperatures as they decreased at a rate of only 0.1°C/min (1°C (2°F) over the 10 minute period). Fire fighters on the third platform later reported the ventilation alignment did improve tenability conditions on the third platform once mechanical ventilation commenced. Although improvements in tenability conditions were reported by test personnel on the third platform, the improvements were not measured by the instrumentation and could not be quantitatively verified. The visibility in CPO/Crew Mess reached a minimum of 4% as active ventilation commenced.

The ventilation improved visibility in CPO/Crew Mess to 47% by the end of the test. A number of test participants changed OBA canisters during the test in compartments that were smoky and reported no difficulty. At 33 minutes, 4 seconds after the fire was ignited, the test was secured. Conditions in the Control Room/DC Central did not improve significantly, but the conditions throughout the boat improved noticeably compared to Tests sub8_01 and sub8_02 as a result of the modified emergency ventilate mode using the supply fan.

The tenability threshold limits for visibility and temperature were exceeded for essentially the entire test. This was a result of a severe fire threat and nearly 18 minutes of fire fighting efforts. Soon after fire fighting efforts began, the temperature threshold limit in the Control Room/DC Central was exceeded. Temperatures decreased to approximately 48°C (118°F) 1.5-m (5-ft) above the deck by the end of the test. The visibility in the Control Room/DC Central was 0% for 20 minutes, only starting to improve after emergency ventilation commenced.

The Control Room/DC Central visibility, measured by the two ODMs, is shown in Figure 34. The corresponding measured temperatures are shown in Figure 35. Figure 32 shows the comparison in visibility in the Control Room/DC Central for Tests sub8_01, sub8_02 and sub8_03. The comparison of the compartment temperatures for all three tests is shown in Figure 33. The timeline of key events for Test sub8_03 can be found in Appendix H.

13.5 Test sub8_04

The fourth test involved a Class A wood crib and a Class B diesel pan fire located in AMR. Access to the fire was restricted by the obstructions in AMR and the location of the wood crib within Obstruction 3. Initially the boat was at periscope depth. After the fire was called away, the boat proceeded to the surface. A 5 minute delay (simulating the time required to align the proper valves, dampers, fans, open the bridge hatch) was introduced from the time the fire was called away until initiation of mechanical ventilation could begin.

The fire was called away over the 1MC by the Control Room/DC Central 4 minutes, 17 seconds after ignition. This time included a 2 minutes, 34 second delay before releasing the Watchstander. This delay was artificially introduced to allow the fire time to grow. The Watchstander retrieved the AFFF extinguisher from the Torpedo Room forward and returned to the AMR and expended the extinguisher on the Class A fire. After the first AFFF extinguisher was expended, the first Rapid Responder was on scene with a second AFFF extinguisher taken from the base of the ladder in Laundry. The Rapid Responder reported that he had good visibility upon entering the AMR. The AFFF was used to extinguish the Class B fire first, using approximately ¼ of the bottle. With the remaining AFFF, the first Rapid Responder expended the remaining contents on the Class A fire with little effect while trying to gain access to the seat of the Class A fire. The peak temperature of 58°C (136°F) was recorded in the Control Room/DC Central at this time.

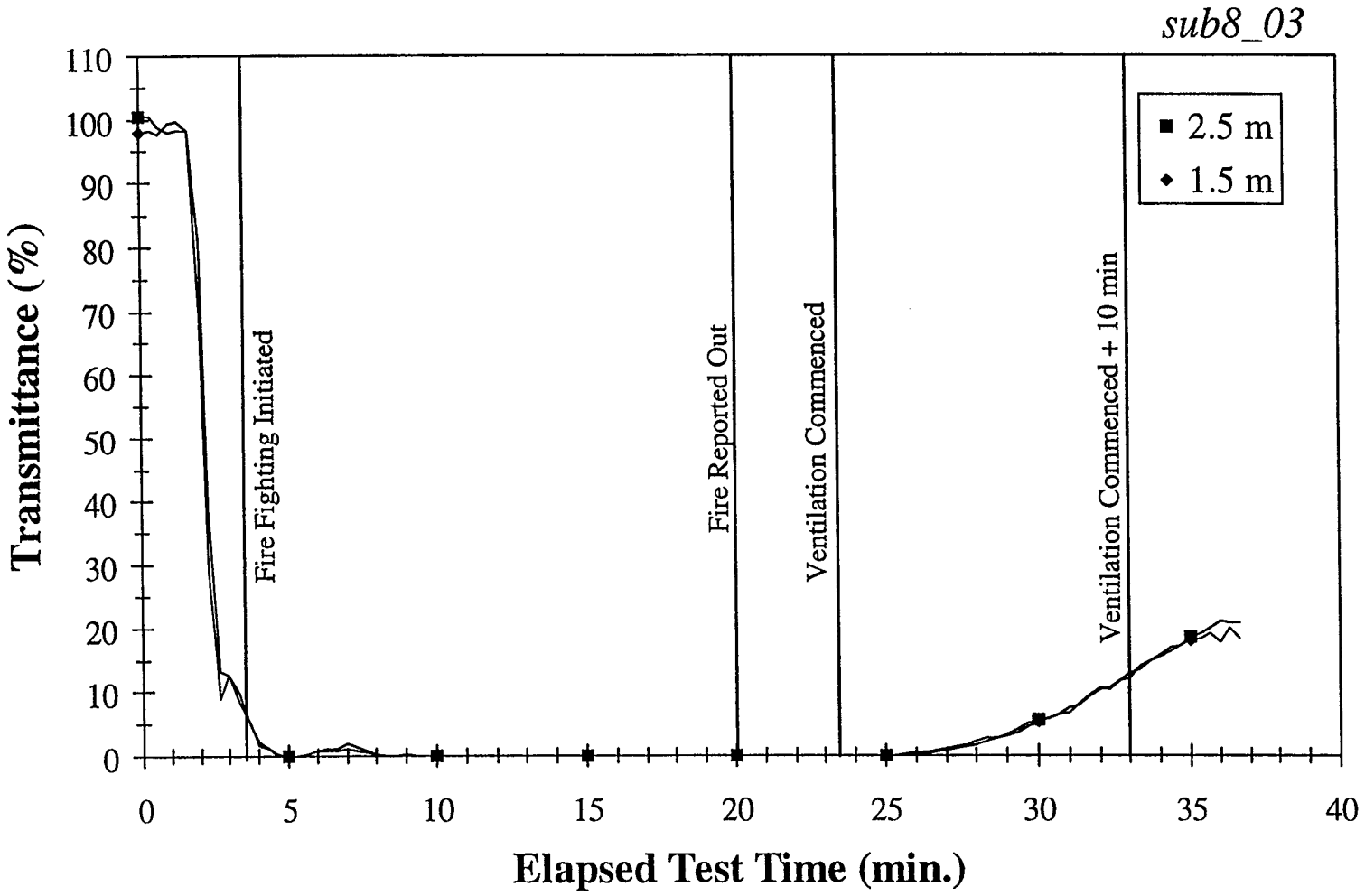


Fig. 34 – Control Room/DC Central visibility, Test sub8_03

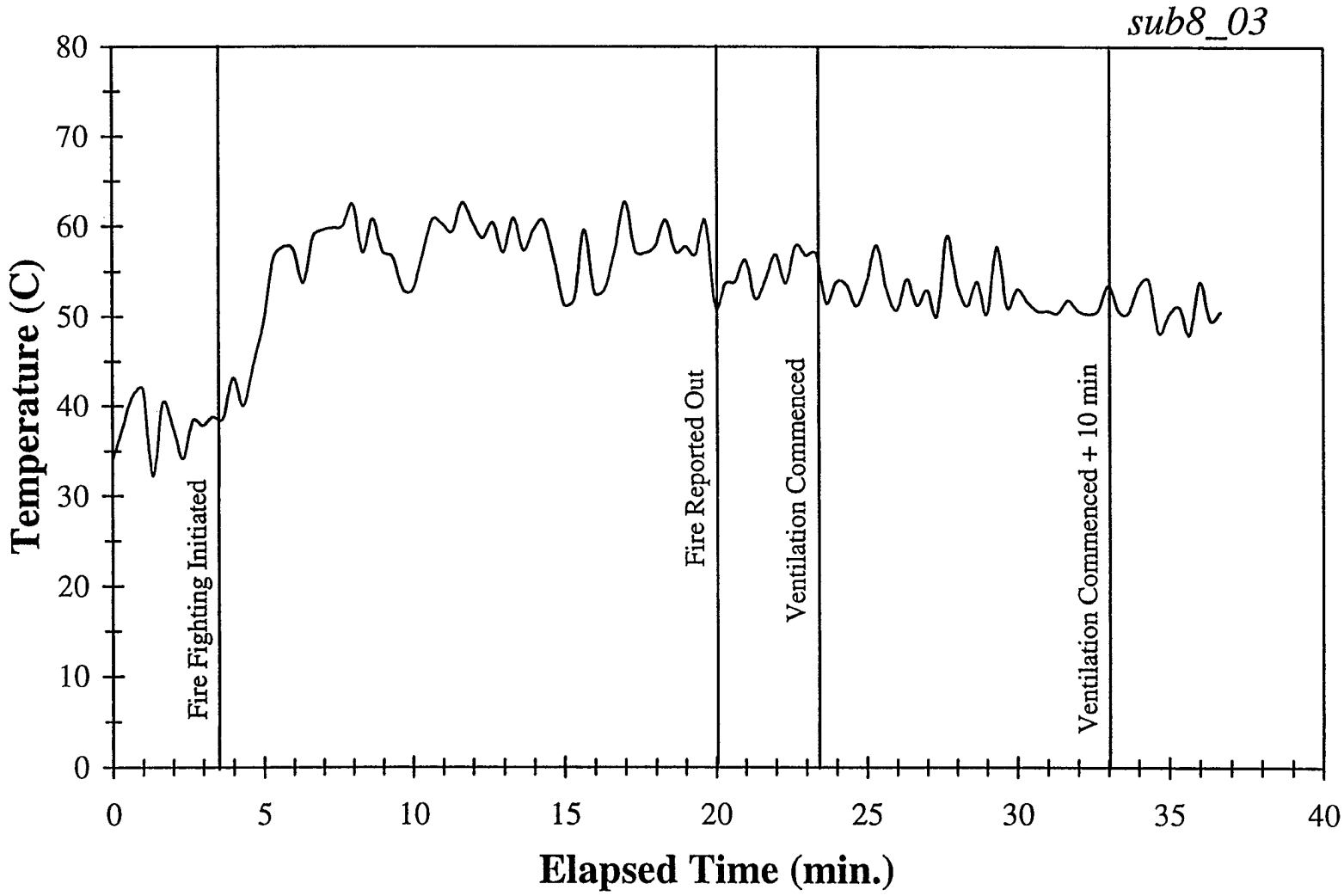


Fig. 35 – Control Room/DC Central temperature, Test sub8_03

Five minutes after the fire was called away, the boat reached the surface. The Casualty Coordinator was notified of the boats position and initiated procedures to prepare the boat for a Control Room Sweep. Nine minutes after the fire was called away, the Control Room Sweep commenced with the L.P. blower exhausting air from the NAV Equipment Room. Ten minutes 5 seconds after the fires were called away, the bridge hatch was opened providing an inflow of fresh air. The Control Room/DC Central reported visibility improving 30 seconds later. The ODMs in the Control Room/DC Central measured 0% visibility at 10 minutes and improved to 90% once the L.P. blower was operating, and the bridge hatch opened. The Man-in-Charge also reported conditions improving in AMR for heat and smoke levels.

Simultaneous with the beginning of mechanical ventilation, a PKP extinguisher was brought in to AMR, but failed to work when operated. A second PKP bottle from Torpedo forward was used in conjunction with another AFFF bottle and the Class A fire was knocked down. The remaining Rapid Responders rigged the primary hose from the Torpedo Room aft plug and used short blasts to cool any remaining hot spots before the primary nozzleman arrived. The hose in Torpedo forward was rigged as the secondary hose, but never used. Both fires were reported out by the Man-in-Charge 15 minutes, 18 seconds after they were ignited. Seventeen minutes, 11 seconds after the fires were called away, the supply fan was started to augment the Control Room Sweep for post-fire desmoking. At approximately 18 minutes, 44 seconds later, the Man-in-Charge reported improving conditions in the AMR.

Thirty-four minutes, 37 seconds after the fires were ignited, the test was secured as conditions were improving throughout the test space. A total of 852 ℓ (225 gal) of water was used during the test. The Control Room/DC Central visibility is shown in Figure 36 as measured by the ODMs. The compartment temperatures are shown in Figure 37.

In Test sub8_04, active desmoking was evaluated. While fire fighting efforts were ongoing, a Control Room sweep was initiated. Over the next six minutes, prior to the fire being extinguished, the visibility in the Control Room/DC Central recovered at a rate of 13.2 %/min and the temperatures recovered at a rate of 4.4°C/min. In measurable terms, the visibility improved from 5% to 88% transmittance and the temperatures dropped from 55°C (131°F) to 27°C (81°F). During the 10 minutes following the extinguishment of the fire, the rate of recovery of both visibility and temperature slowed slightly, 8.7 %/min for the Control Room/DC Central visibility and -0.1°C/min for temperature. The negative rate of recovery in the Control Room/DC Central temperature occurred during a slight increase in temperature, but temperatures were already about the same as pre-test temperatures.

There was a noticeable temporary drop in the Control Room/DC Central visibility and a slight increase in temperature 22 minutes after the fires were ignited. This was presumably due to the supply fan being started and temporarily causing a change in the flow patterns throughout the boat. This event was reported by the Casualty Coordinator as a slight increase in the amount of smoke that flowed into the Control Room/DC Central, down the command passageway from Combat Systems. Although this was a temporary decrease in the Control Room/DC Central

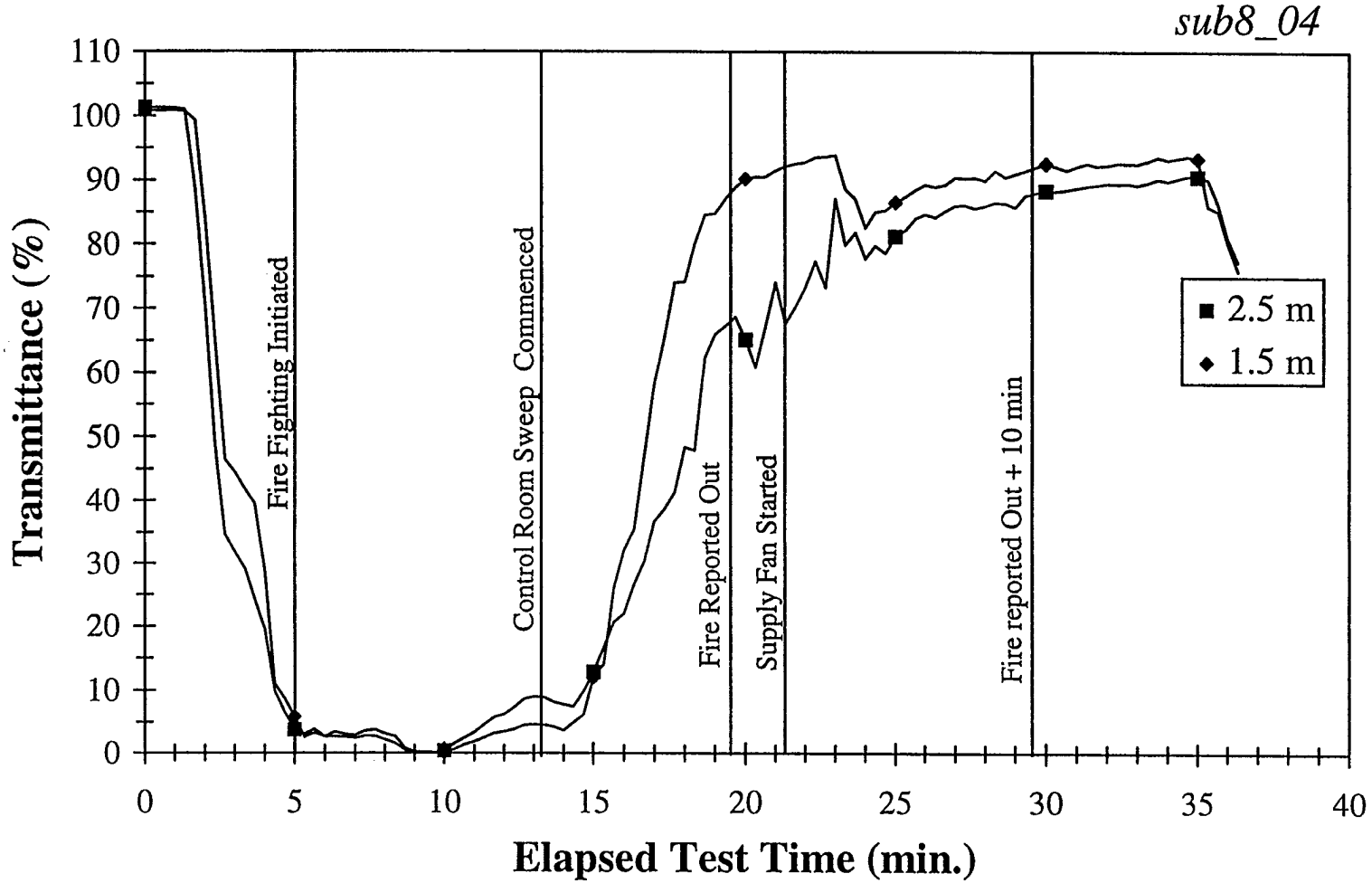


Fig. 36 – Control Room/DC Central visibility, Test sub8_04

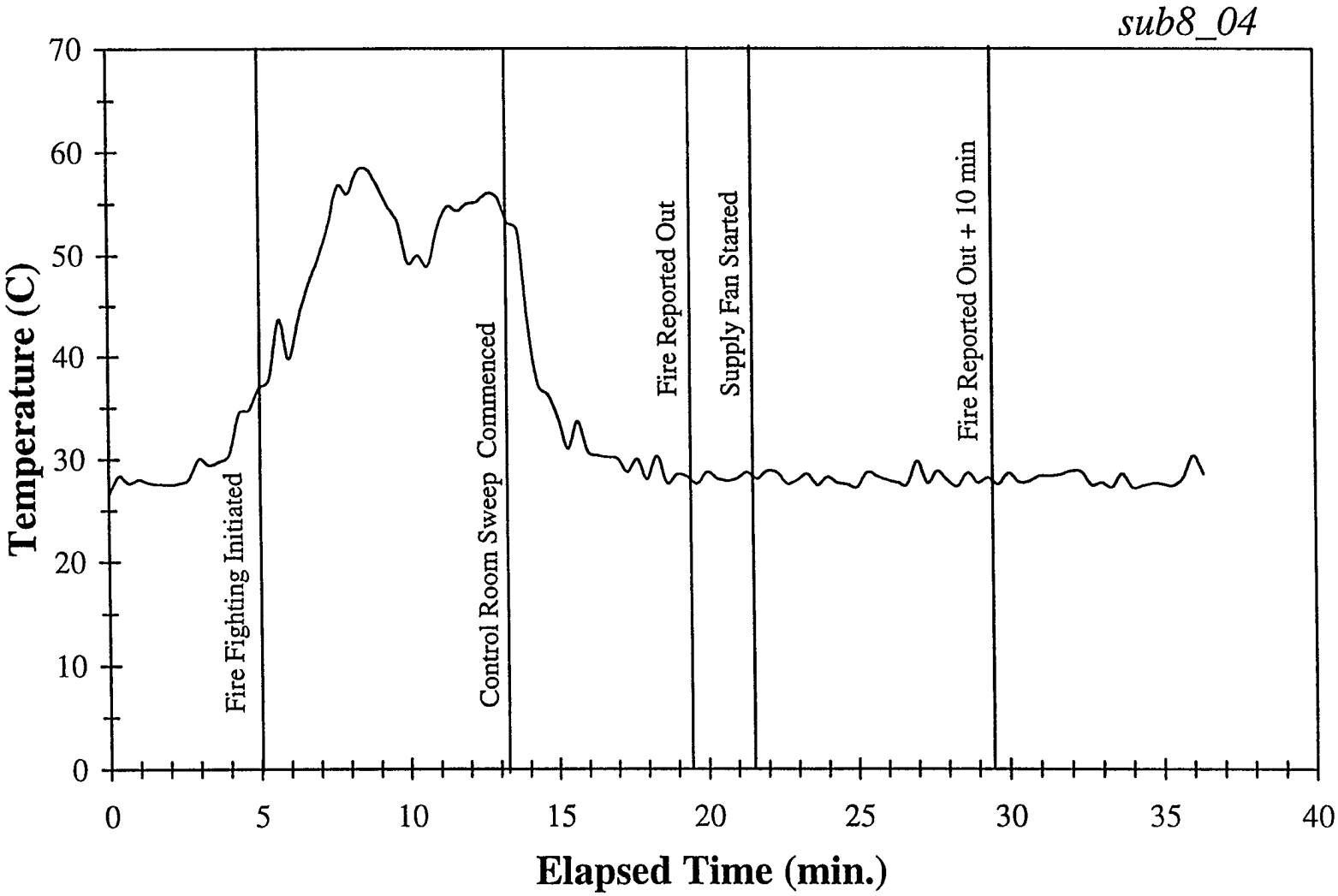


Fig. 37 – Control Room/DC Central temperature, Test sub8_04

tenability conditions, once flow patterns were re-established, the tenability conditions recovered. The Man-in-Charge reported a noticeable clearing and improvement in tenability conditions once ventilation commenced and especially once the supply fan was started. No ODMs were located in AMR due to the increased potential for damage due to heat, so this improvement in visibility could not be confirmed. The thermocouples in AMR and Laundry did not record any significant decreases in compartment temperatures above the established recovery rates. The timeline of key events for Test sub8_04 can be found in Appendix H.

13.6 Test sub8_05

The test parameters (fire scenario and boat position) used in this test were identical to Test sub8_04. The difference between these tests was the order in which the ventilation fans were started. The objective of this test was to evaluate the effect of active desmoking on overall tenability conditions. This was not accomplished as the fire was extinguished prior to commencement of ventilation. Also examined was the effect of changing the order of fan operation and the impact on fire growth. When the Control Room Sweep commenced, the bridge hatch was to be opened and the L.P. blower, exhausting from the NAV Equipment room, was to be started. One minute later, the supply fan was to be started. One minute after the supply fan was started, the induction fan was to be started.

Three minutes, 15 seconds after the fires were ignited, the Watchstander reported the fire in AMR to the Control Room/DC Central. This time included an artificial delay of 1 minute, 30 seconds to allow the fire to grow to the desired size. Upon seeing and reporting the fire, the Watchstander grabbed the AFFF extinguisher located at the base of the ladder in Laundry. The Class B diesel pool fire was extinguished first, using approximately ¾ of the bottle. The temperatures in the Control Room/DC Central were at a maximum of 48°C (118°F) at 1.5-m (5-ft) above the deck, prior to the Watchstander initiating fire fighting activities. The ODMs in the Control Room/DC Central measured a temporary increase in visibility from 12% to 35% when the Class B fire was extinguished. With the Class B fire out, the Watchstander used the remaining AFFF to attack the Class A fire. When the Rapid Response Team arrived, two more AFFF extinguishers and one PKP extinguisher were used to extinguish the Class A fire. Seven minutes, 5 seconds after the fire was called away, the Man-in-Charge reported to the Control Room/DC Central that both fires were out. The primary hose was pulled from Torpedo Room aft by the Rapid Response Team. This hose was charged, but used only to cool hot spots. A total of 132 ℓ (35 gal) of water was used during the test. During fire fighting efforts, the visibility in the Control Room/DC Central reached a minimum of 3 %. Between the time when the fire was reported out and mechanical ventilation commenced, the visibility in the Control Room/DC Central recovered at a rate of 0.8 %/min (from 7% to 17%) and temperatures decreased at a rate of 0.2°C/min (from 45°C (113°F) to 42°C (108°F)).

Nine minutes, 32 seconds after the fire was called away, the boat reached the surface (5 minutes, 23 seconds after the decision to surface was made by the Casualty Coordinator). The L.P. blower exhausted air from the NAV Equipment Room, and the bridge hatch was open.

Forty seconds later at 10 minutes, 10 seconds after the fire was called away, the supply fan was started. The starting of the supply fan caused an immediate improvement in the Control Room/DC Central visibility from 20% to 75 % over the next minute. At 11 minutes, 20 seconds after the fire was called away, the exhaust fan, aligned as the induction fan, was started. The visibility in the CPO/Crew Mess reached 38% prior to initiating ventilation and improved to 94% by the end of the test. During the 10 minute period following the commencement of ventilation, the visibility in the Control Room/DC Central recovered at a rate of 7.7 %/min to 92% by the end of the test. During the same time, the temperatures in the Control Room/DC Central recovered at a rate of 0.7°C/min to 28°C (82°F) by the end of the test. The Man-in-Charge reported conditions improving on the lower platforms as a result of the ventilation fans. At 18 minutes, 45 seconds after the fire was ignited, the exhaust terminal for the L.P. blower was changed from the NAV Equipment Room to the AMR. The Man-in-Charge reported quicker improvement of conditions on the lower platforms. Twenty-eight minutes, 10 seconds after the fires were ignited, the test was secured. When the test was secured, the visibility was back to 100% and the temperatures were down to their pre-test levels. The combination of the supply fan and the bridge hatch significantly recovered tenability conditions in the Control Room/DC Central. Tenability conditions were also improved in other compartments on the lower platforms.

The visibility as measured by the two ODMs in the Control Room/DC Central is shown in Figure 38. The effect of ventilation and fire fighting on the Control Room/DC Central temperature is shown in Figure 39. Figure 40 shows a comparison of the visibility in the Control Room/DC Central for Tests sub8_04 and sub8_05 at the 1.5-m (5-ft) high ODM. The effect of the supply fan and the induction fan improving visibility is shown in Figure 40. A comparison of the temperatures at 1.5-m (5-ft) off the deck for both tests are shown in Figure 41. The timeline of key events for Test sub8_05 can be found in Appendix H.

13.7 Test sub8_06

The fire scenario used in this test was a Class A wood crib fire located in the Laundry Fire Compartment, initiated in a metal cabinet directly underneath the overhead opening to the wooden framebay mockup on the second platform. The fire extended up into the wooden framebay and vented into the Control Room. This fire scenario provided a more challenging, multi-deck/concealed space fire. Initially, the boat was at periscope depth. After the fire was called away, the boat proceeded to the surface. A 5 minute delay was introduced from the time the fire was called away until initiation of mechanical ventilation could begin. Once the boat reached the surface, and "Commence Control Room Sweep" was called away, the bridge hatch was to be opened and the L.P. blower, exhausting out of the NAV Equipment room, was to be started. Once the fire was reported out, the supply fan was to be started. One minute after the supply fan was started, the induction fan was to be started. The effect of sequencing the fan operation with fire extinguishment on the overall tenability conditions was to be evaluated.

Four minutes, 20 seconds after the wood crib was ignited in the metal cabinet, the Watchstander reported to the Control Room/DC Central a fire in the Laundry compartment.

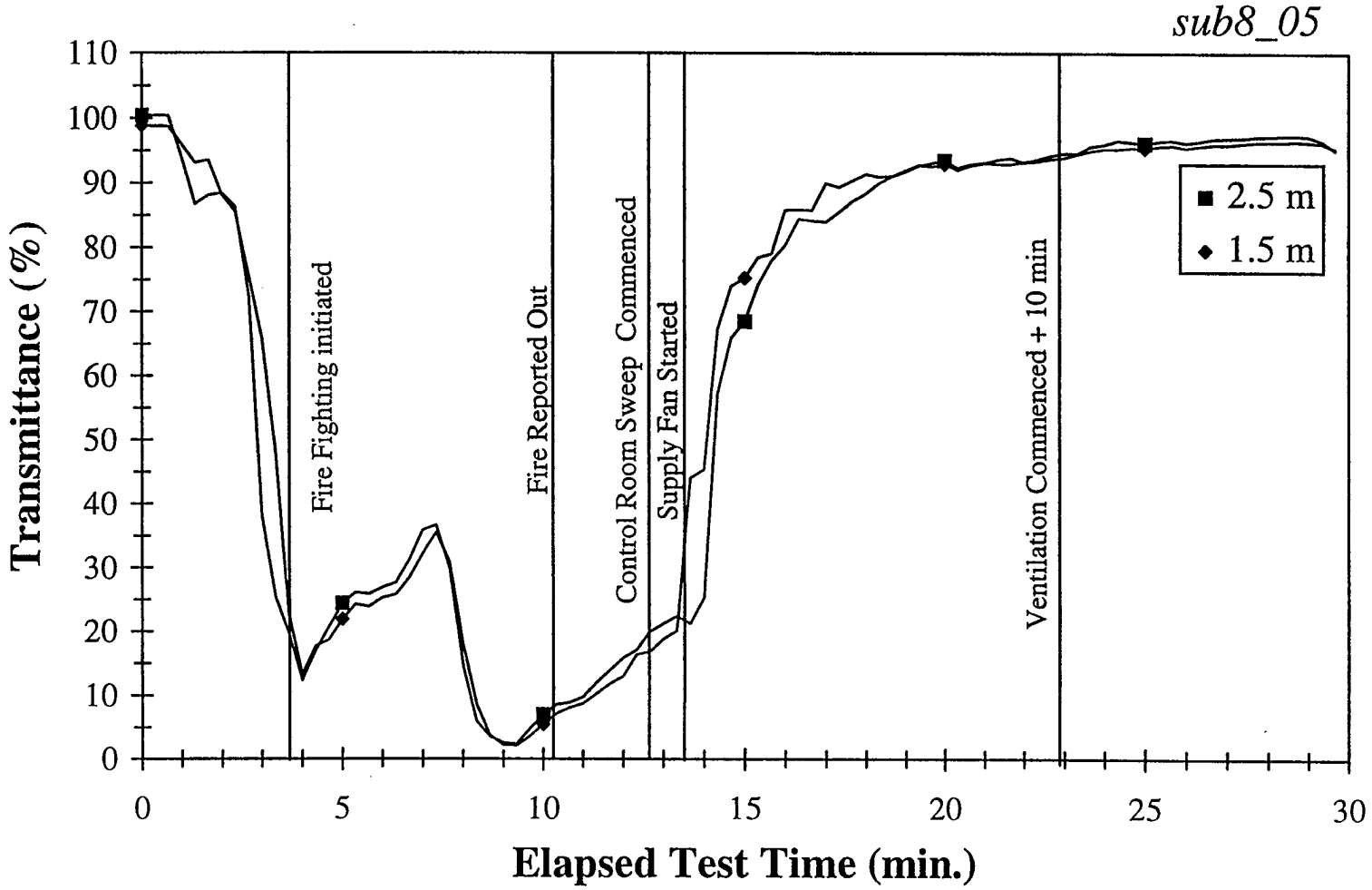


Fig. 38 – Control Room/DC Central visibility, Test sub8_05

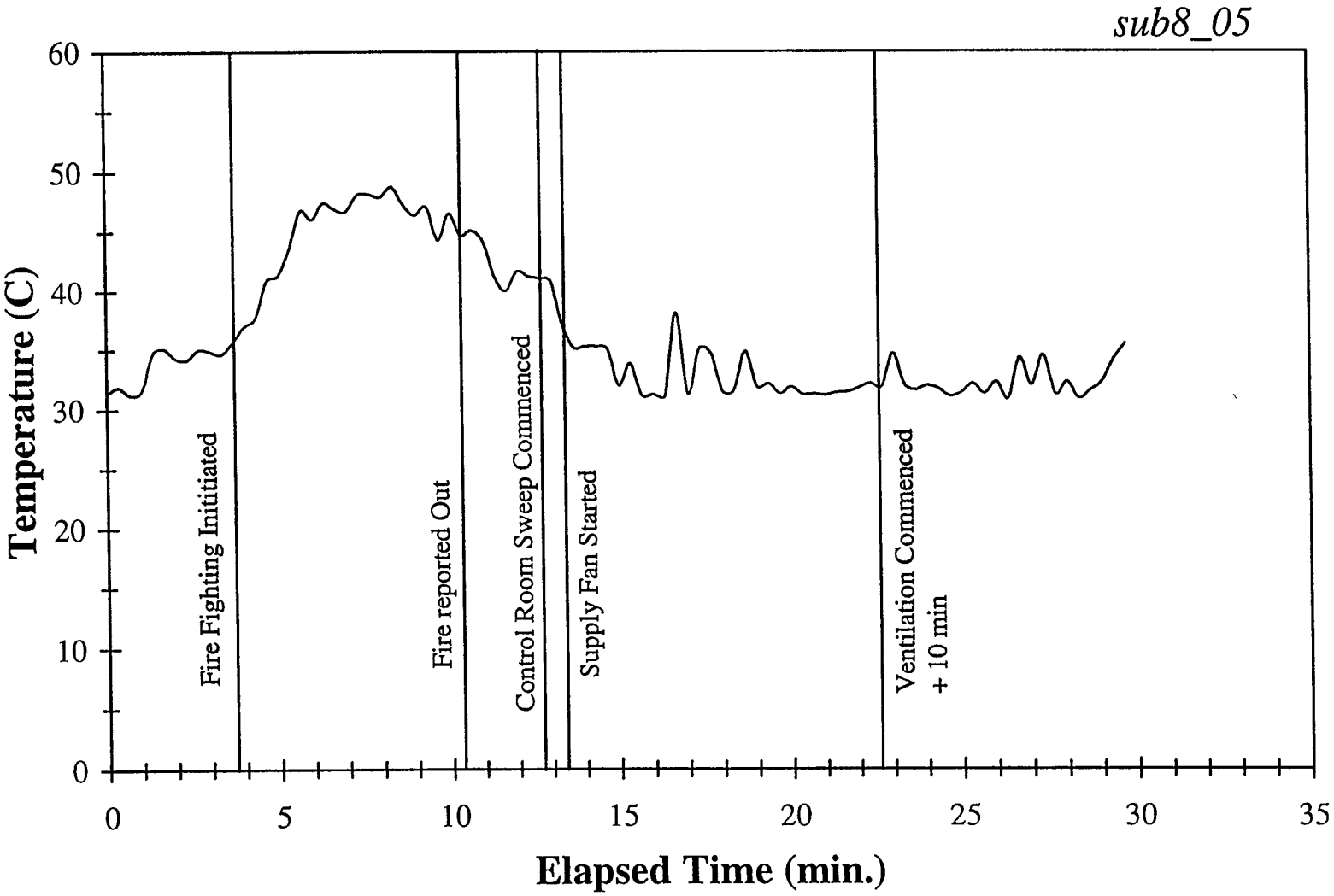


Fig. 39 – Control Room/DC Central temperature, Test sub8_05

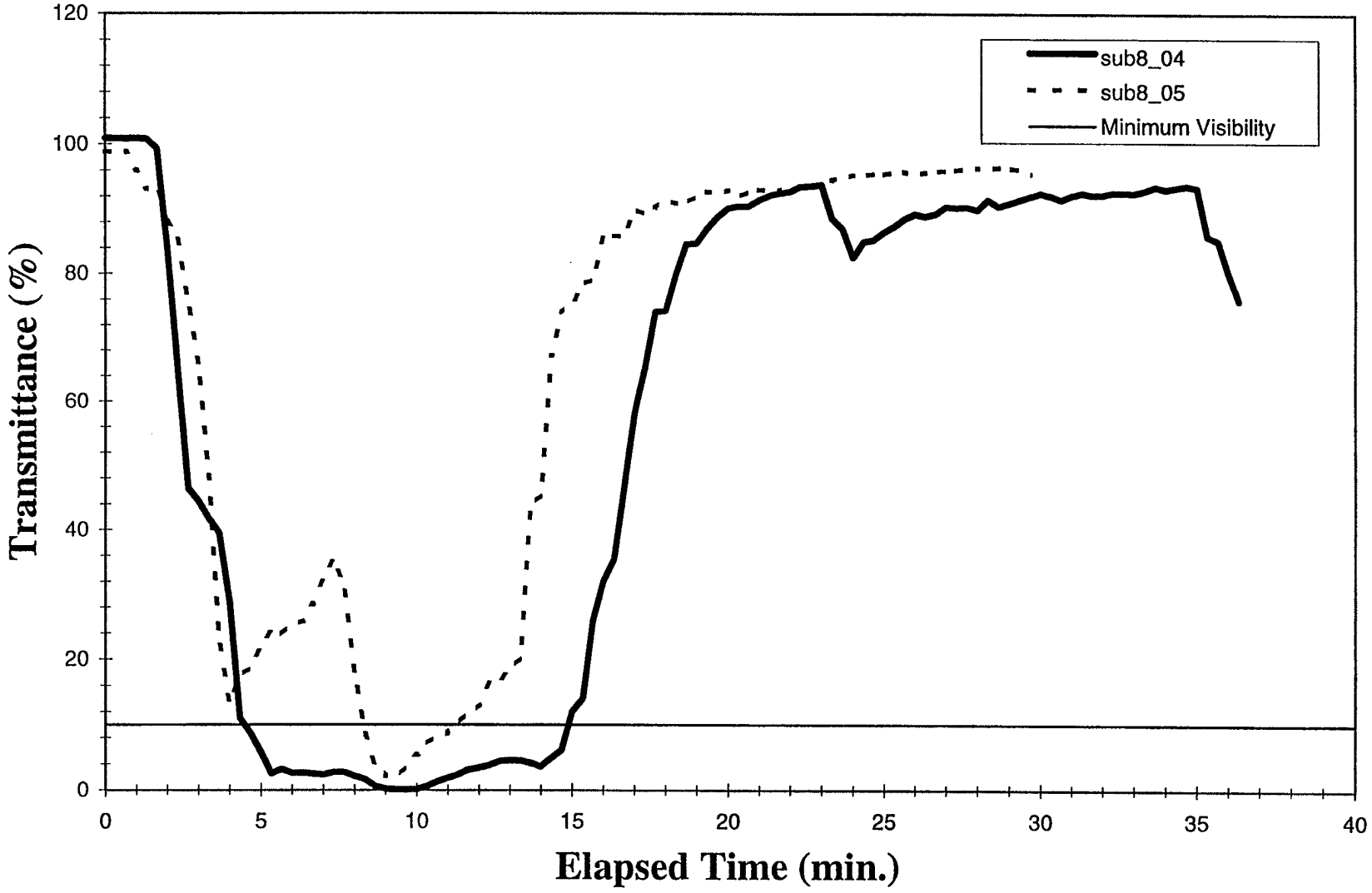


Fig. 40 – Control Room/DC Central visibility (1.5 m ODMs), Test sub8_04 and _05

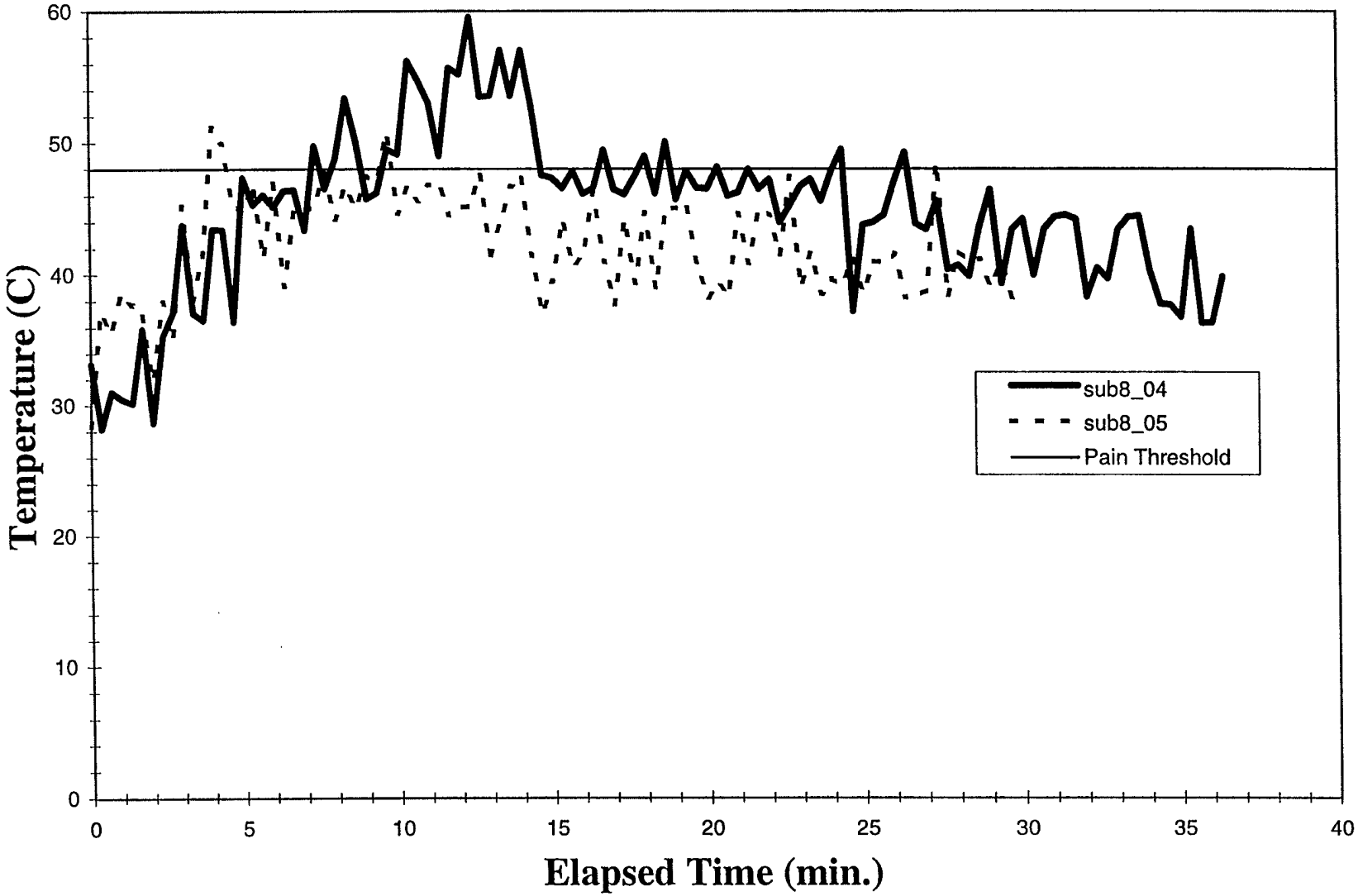


Fig. 41 – Control Room/DC Central temperatures (1.5 m TC's), Test sub8_04 and _05

There was approximately a 3 minute delay in releasing the Watchstander to allow the fire to grow in the Laundry space and spread vertically upward through the framebay. In the Control Room/DC Central, the visibility quickly dropped to 28% one minute after ignition. This was most likely due to the smoke produced from the initiating pan fire in the metal cabinet. Since the cabinet was located directly below the opening for the framebay, smoke was directed up into the Control Room/DC Central. As the initiating pan fire burned out, the visibility improved to 75% over the next four minutes. The Watchstander reported heavy smoke going down the ladder onto the third platform and was forced to go on air. He picked up the AFFF extinguisher at the base of the ladder, moved to the Laundry Fire Compartment and reported that the door was locked. The Watchstander was forced to leave the scene and went to CPO/Crew Mess. Approximately 6 to 7 minutes after the fire was ignited, the visibility in the Control Room/DC Central dropped to 0% and the temperatures peaked at 147°C (297°F).

The first Rapid Responder went directly into the Wardroom after noticing fire in the wooden framebay mockup. Using a PKP extinguisher, he discharged it through the cracks around the framebay and knocked down the visible flames. The second Rapid Responder grabbed the water bottle just outside the Wardroom and entered the Wardroom to assist the first Rapid Responder. The second Rapid Responder discharged the water extinguisher in the cracks of the framebay, completing extinguishment of the fire. The Rapid Responders left the Wardroom and proceeded down to the Laundry compartment. With the framebay fire knocked down, the temperatures in the Control Room/DC Central dropped to 63°C (145°F) and the visibility improved to 10%. The Rapid Responders kicked in the lower door panel of the Laundry Fire Compartment Door and expended the AFFF extinguisher and fired two short bursts of the PKP into the compartment. It is unknown if the two extinguishers were discharged toward the metal cabinet, behind the door, or if the extinguishers were discharged forward into the compartment where the previous Laundry fires were located. The primary hose for the Laundry fire was pulled from Torpedo Room aft by the Rapid Response Team. This hose was charged and used to cool hot spots. The secondary hose was pulled from the mid-platform passageway into the Wardroom. The hose was also charged and used to cool hot spots. A total of 182 ℓ (48 gal) of water was used during the test.

Ten minutes, 55 seconds after the fire was called away, the Man-in-Charge reported to the Control Room/DC Central that all fires were out. One minute later (15 minutes, 17 seconds after the fires were ignited) the bridge hatch was opened and the L.P. blower, exhausting from the NAV Equipment Room, was started. Prior to opening the bridge hatch and starting the L.P. blower, the visibility in the Control Room/DC Central was recovering at a rate of 2.2 %/min, from 25% to 26%, and temperatures remained constant. These recovery rates between the time that the fire was reported out and ventilation commenced encompassed 27 seconds, so a 1% change on visibility calculated to a misleading quick recovery rate. Starting the L.P. blower and opening the bridge hatch quickly improved the Control Room/DC Central visibility to 55% and decreased temperatures by 10°C (18°F). Seventeen minutes, 2 seconds after the fires were ignited, the supply fan was started. This improved the Control Room/DC Central visibility to 83%. The induction fan was started 21 minutes 31 seconds after the fires were ignited. During the ten

minute period following commencement of ventilation, the visibility in the Control Room/DC Central improved at a rate of 5.7 %/min (from 26% to 83%). Temperatures in the Control Room/DC Central recovered at a rate of 1.4°C/min, from 51°C (124°F) to 37°C (99°F). Thirty-two minutes, 41 seconds after igniting the fires, the test was secured.

Visibility in the Control Room/DC Central, as measured by the two ODMs, is shown in Figure 42. Figure 43 shows the fire fighting and ventilation effects on the compartment temperatures in the Control Room/DC Central. The timeline of key events for Test sub8_06 can be found in Appendix H.

13.8 Test sub8_07

The fire scenario for Test sub8_07 was a culmination of all of fires from the previous tests. There were Class A and Class B fires in the AMR, the Class A fire in the Laundry Fire Compartment, and a Class A fire initiated in the metal cabinet in the Laundry Fire Compartment which extended up into the wooden framebay mockup on the second platform. This scenario presented the fire fighters with a very challenging multi-deck, multiple fire source scenario. The initial positioning of the boat (periscope depth) and the operation of the ventilation fans were the same as Test sub8_06.

The Watchstander was released 2 minutes, 8 seconds after the fire was ignited. The fire was called away over the 1MC at 2 minutes, 47 seconds. The Watchstander picked up the AFFF extinguisher at the top of the ladder going down into Laundry and proceeded into the Laundry Fire Compartment forward. He reported that it was hot in the fire compartment, but he could get close to the fire. He discharged a couple of short bursts at the fire, causing it to flash up to the overhead, and over his head back aft, approximately half the depth of the compartment. The Watchstander put down the AFFF extinguisher and exited the space to get another portable extinguisher. The Man-in-Charge went directly to Laundry once the fire was called away. The Watchstander had just left and was returning shortly with a PKP extinguisher from the Torpedo Room. The Watchstander fired four or five short bursts with the PKP extinguisher and knocked down the fire. The Watchstander reported he then picked up the original AFFF extinguisher and cooled down any remaining hot spots. While the Watchstander was fighting the fire in Laundry, the Man-in-Charge noticed the AMR fire and called to inform the Control Room/DC Central of a second fire 5 minutes, 49 seconds after the fires were ignited. The Man-in-Charge then proceeded to AMR.

When the Man-in-Charge entered the AMR and noticed the fire, he left and retrieved the other PKP extinguisher from the Torpedo Room. At this time (approximately 4 minutes after the fires were called away), the maximum temperature of 75°C (167°F) was measured in the Control Room/DC Central. As the Man-in-Charge was extinguishing the Class A fire, the safety team stopped him to prevent the fire from being extinguished prior to the arrival of the Rapid Responders. The first Rapid Responder grabbed the 1.9-cm (0.75-in.) hose reel located in the second platform passageway and proceeded to AMR after hearing the location of the second fire

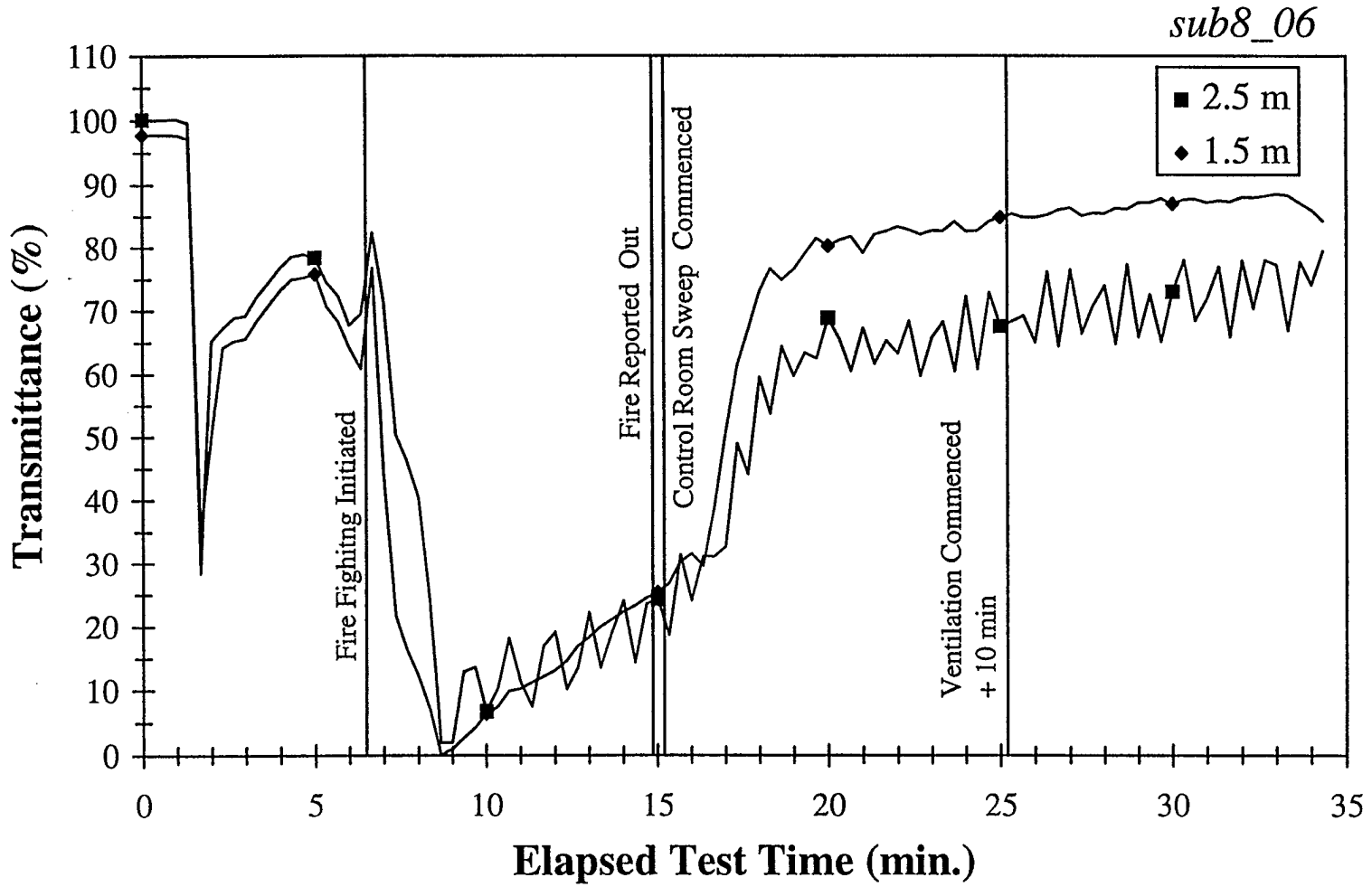


Fig. 42 – Control Room/DC Central visibility, Test sub8_06

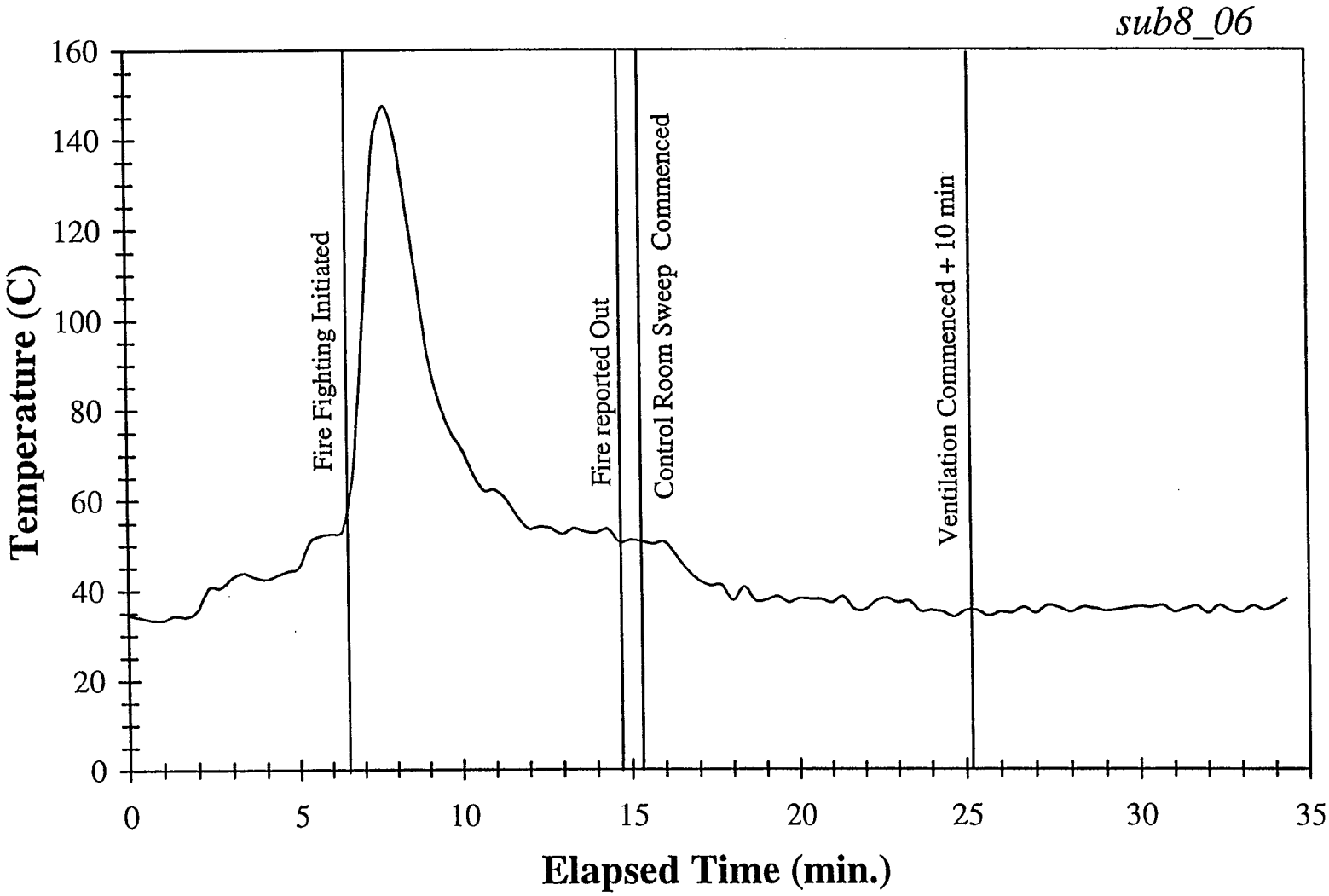


Fig. 43 – Control Room/DC Central temperature, Test sub8_06

over the 1MC. He applied water to the seat of the fire, but stated that the hose was a little too short, preventing him from applying water directly on the fire. The fire in AMR was reported out 6 minutes, 14 seconds after the first fire was called away. At about the time the fire in AMR was extinguished, the visibility in the Control Room/DC Central was 0%, but the temperatures had dropped to 57°C (135°F).

The second 1.9-cm (0.75-in) hose reel was pulled by the primary nozzleman of the primary Hose Team from CPO/Crew Mess. The hose reel was advanced down the ladder going to Laundry and into the Laundry Fire Compartment. As the 1.9-cm (0.75-in.) hose was stretched into the fire compartment, the primary 3.8-cm (1.5-in.) hose line was rigged from torpedo aft and brought into Laundry to cool any remaining hot spots. The fire in Laundry was reported out 6 minutes, 37 seconds after the fire was called away. A total of 534 ℓ (141 gal) of water was used to extinguish the fires. The Class A wood crib in the metal cabinet underneath the wooden framebay, the contents of the wooden framebay, and the Class B fire did not ignite. During the period between when the fires were reported out and ventilation commenced (1 minute, 20 seconds) there was negligible recovery in the Control Room/DC Central visibility (0.8 %/min) and the temperatures in the Control Room/DC Central rose slightly at a rate of 3.0 °C/min.

Ten minutes, 21 seconds after the fires were ignited (5 minutes, 32 seconds after the decision to surface was made), the Control Room sweep commenced with the bridge hatch being opened. Twenty seconds later, the L.P. blower, exhausting from the NAV Equipment room, was started. With the Control Room sweep in process, the visibility in the Control Room/DC Central improved to 11%. Twelve minutes, 14 seconds after the fires were ignited, the supply fan was started. One minute later, the induction fan was started. In the 10 minute period following commencement of the Supply Fan/Control Room Sweep, the visibility in the Control Room/DC Central recovered at a rate of 7.0 %/min (from 2% to 72%) and the temperatures recovered at a rate of 0.8°C/min (61°C (142°F) to 53°C (127°F)). By the end of the test, the Control Room/DC Central visibility was 89%. At 30 minutes 49 seconds, the test was secured.

Figure 44 shows the visibility measured by the ODMs in the Control Room/DC Central. The compartment temperatures are shown in Figure 45. A comparison of the compartment visibility for the Control Room/DC Central in Tests sub8_06 and sub8_07 is shown in Figure 46. Again the effect of the ventilation alignment improving visibility is shown. The compartment temperatures for Tests sub8_06 and sub8_07 are shown in Figure 47. The timeline of key events for Test sub8_07 can be found in Appendix H.

13.9 Ventilation Alignment Results

Small Class A and B fires have been shown to be capable of quickly producing untenable smoky conditions on the upper platform, requiring immediate action from personnel. To evaluate options for maintaining tenable conditions, ventilation alignments when the boat was at periscope depth and at the surface were evaluated. Current doctrine specifies that when commencing Emergency Ventilation (after the fire is out) at periscope depth, the induction fan

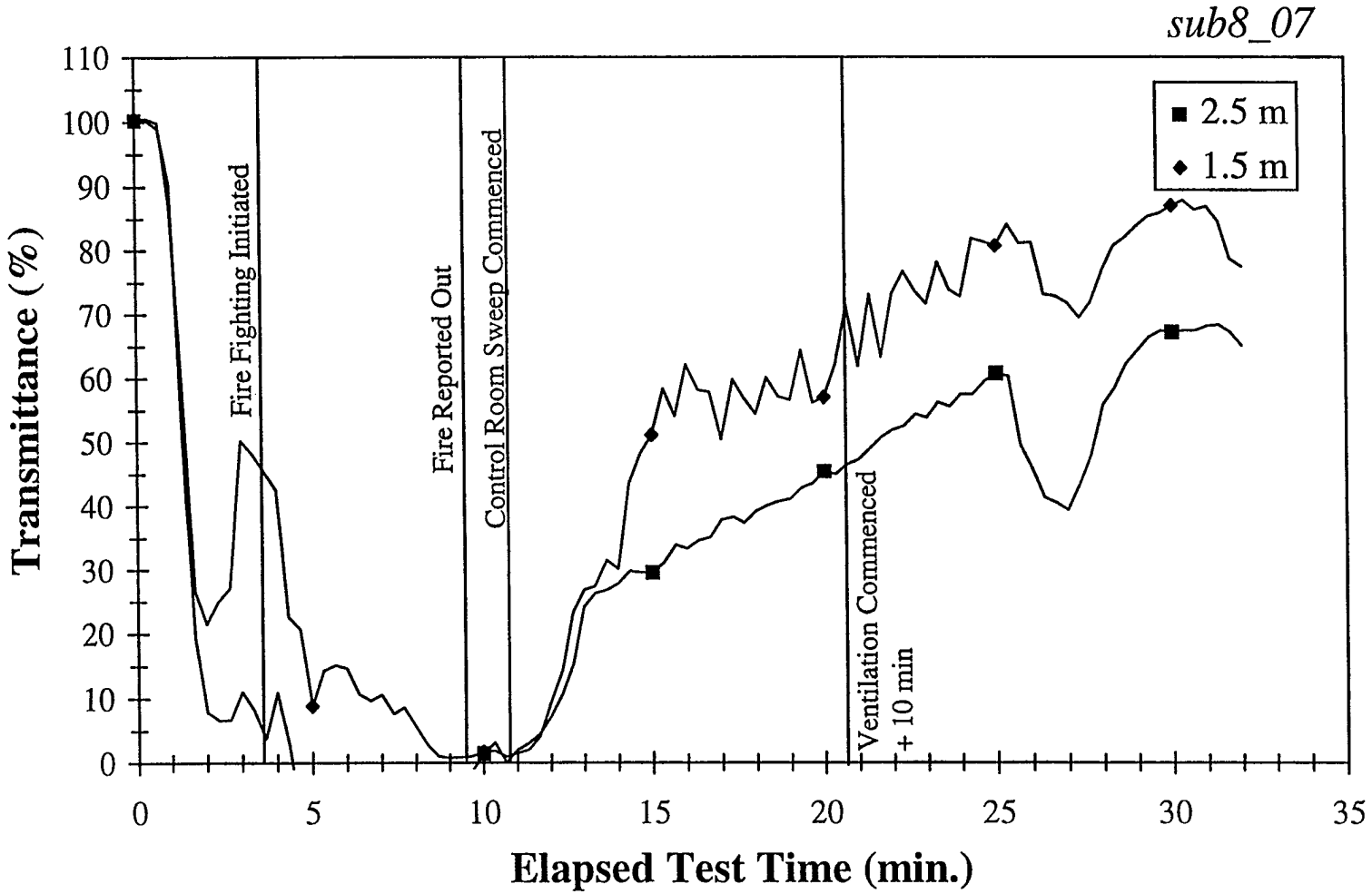


Fig. 44 – Control Room/DC Central visibility, Test sub8_07

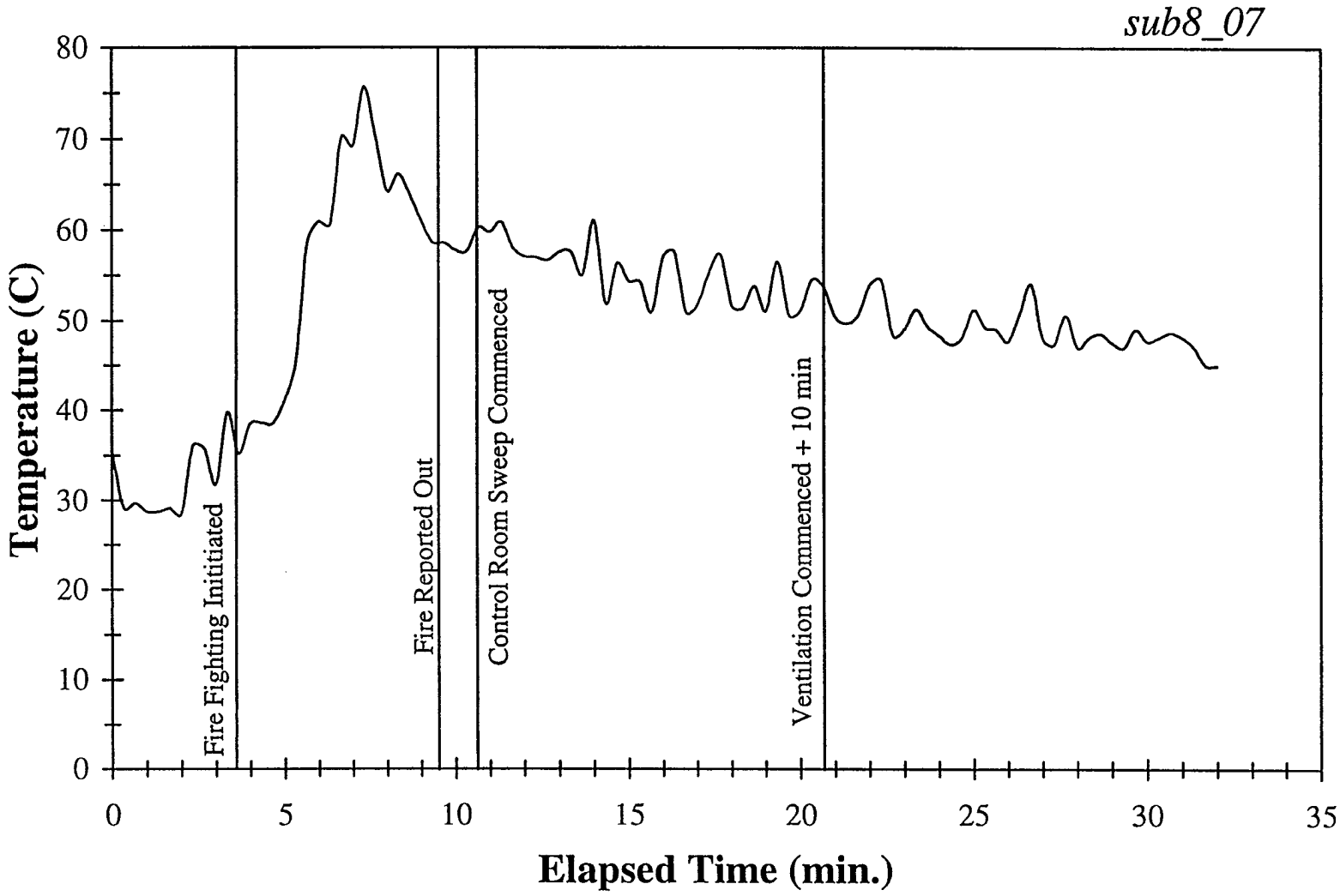


Fig. 45 – Control Room/DC Central temperature, Test sub8_07

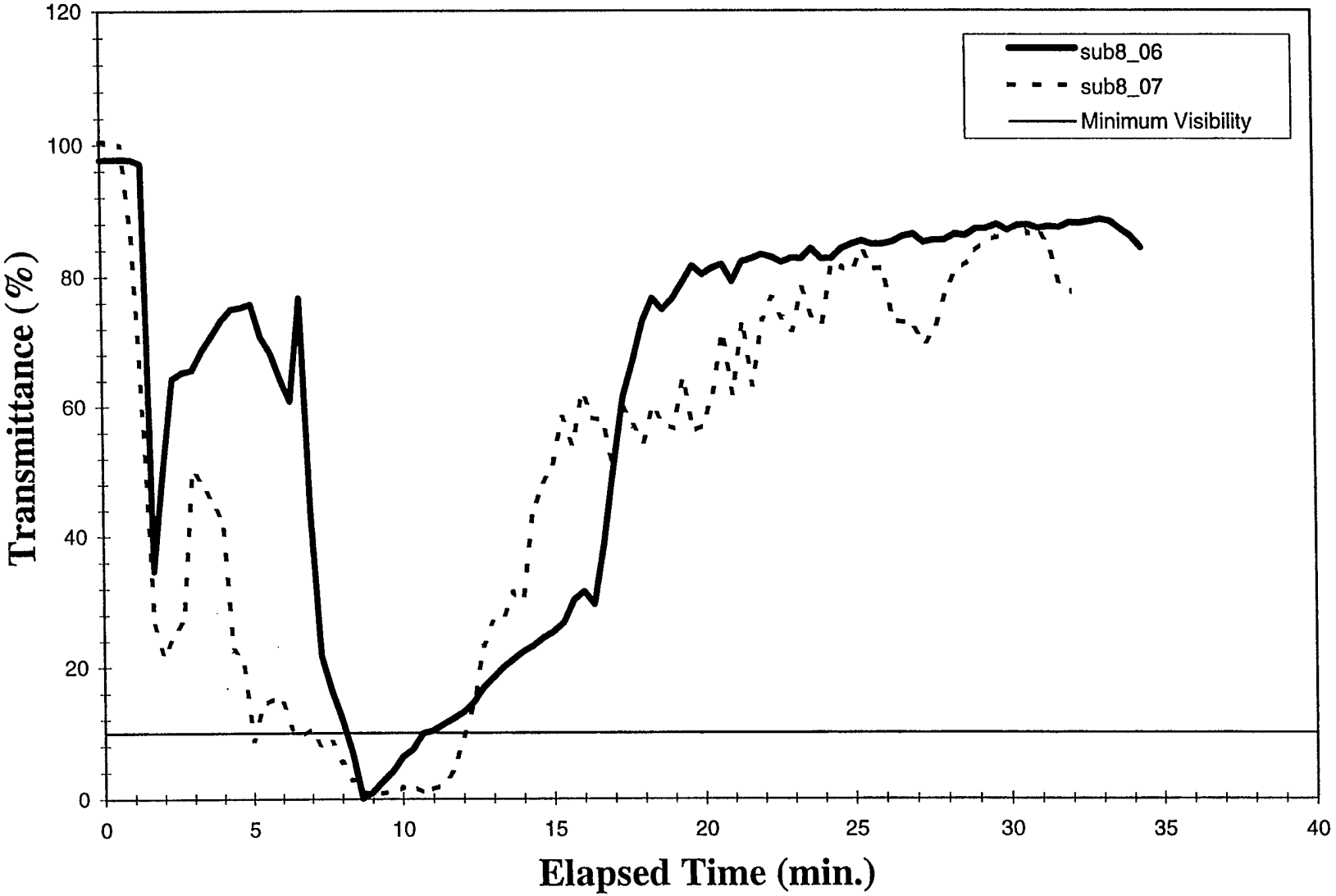


Fig. 46 – Control Room/DC Central visibility (1.5 m ODMs), Test sub8_06 and _07

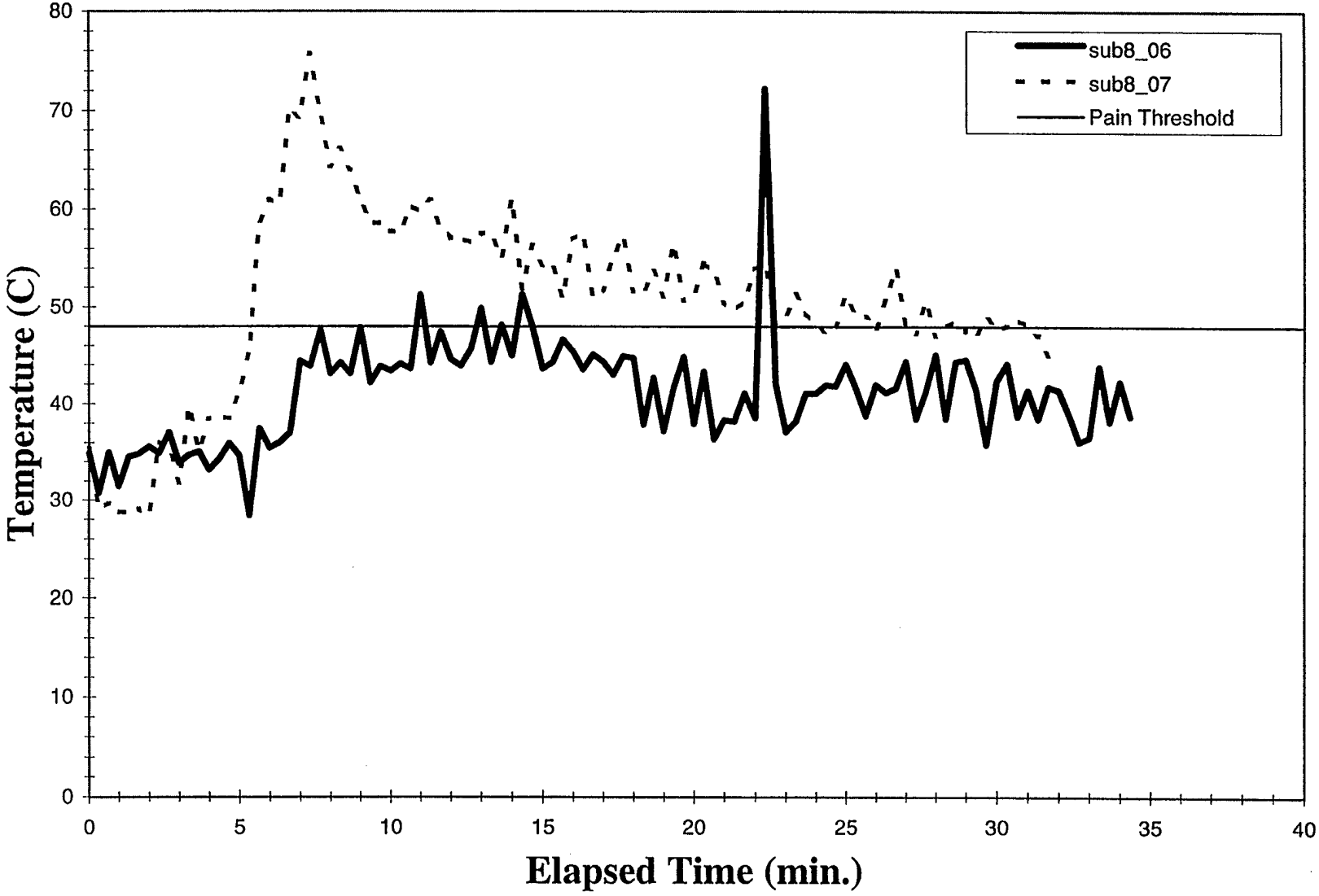


Fig. 47 – Control Room/DC Central temperatures (1.5 m TC's), Test sub8_06 and _07

and the L.P. blower are to be used. This ventilation alignment was used in Tests sub8_01 and sub8_02. It was found that the current emergency ventilate mode fan alignment was capable of recovering tenability conditions in the Control Room for small fires which could be knocked down quickly and produce little smoke. Recovery took longer for larger fires, which produced more severe smoke and heat conditions. In Test sub8_03, the supply fan was used in conjunction with the prescribed emergency ventilation alignment to evaluate if this ventilation alignment would improve tenability conditions in the Control Room. Since the fire scenario was more severe than the fires in the first two tests, producing greater quantities of smoke, a direct comparison was not possible. With more smoke produced in Test sub8_03, recovery of tenable conditions in the Control Room/DC Central was not attained until the end of the test. The supply fan did, however, improve conditions on the lower platforms for test personnel. This improvement was not measured by the instrumentation, so it could not be quantitatively confirmed. Although tenability conditions in the Control Room/DC Central exceeded the threshold limits in Test sub8_03, the Casualty Coordinator stated he retained visual contact with the red LED gauge panel. Additionally, temperatures were not severe enough to have forced him to surface the boat. These statements indicate that the threshold limits for temperature and visibility were conservative, and testing conducted to date has an adequate factor of safety built into the proposed changes to the ventilation alignments.

Table 4 summarizes the rates of recovery for each test. In Table 4, the data from Table 3 are presented as a rate of recovery normalized over time. This allows a direct comparison of rate of recovery for visibility and temperature over the last two key event time periods (between fire reported out and initiation of active ventilation, and the 10 minute period after initiation of active ventilation). For Test sub8_04, where active desmoking was evaluated, the last two key time periods were modified accordingly (the time between the initiation of active ventilation and the fire reported out, and the 10 minute period after the fire was reported out).

The first three tests highlight that without the possibility of either surfacing or using external hatches to vent smoke and heat, the current emergency ventilate mode fan alignment may be unable to preserve or recover tenable conditions in the Control Room/DC Central. Small fires, which produce little heat and modest amounts of smoke, are capable of producing untenable conditions throughout the forward compartment in a short amount of time. Recovery rates for both smoke and heat during the period after the fire was reported out and emergency ventilation commenced were minimal, less than 1 unit (% or °C)/min. During the 10 minute period after the emergency ventilation commenced, recovery of visibility conditions was slightly better, less than 1 %/min to 4 %/min.

In the remaining four tests, the boat "surfaced" and the bridge hatch was opened. Senior test personnel commented that the forward escape trunk hatch would not normally be opened due to the potential for sea wash entering the boat. The lengthy time required to open the weapons loading hatch (10 to 15 minutes) would preclude opening of this hatch in addition to the potential for sea wash entering the boat. For these reasons, only the bridge hatch was opened. In tests sub8_04 and sub8_05, the same fire scenario was used, but the ventilation alignment was

Table 4. Control Room/DC Central Rates of Recovery

Test No.	Scenario	Min %/Max°C During Fire Fighting [FFI - Fire Out]			Rate of Recovery Fire Out to Initiation of Ventilation [1]			Rate of Recovery 10 min Period After Initiation of Ventilation [2]		
		Δ Time (min:sec)	Min. Vis. (%)	Max. Temp. (°C)	Δ Time (min:sec)	Visibility (%/min)	Temp. (°C/min)	Δ Time (min:sec)	Visibility (%/min)	Temp. (°C/min)
sub8_01	Class A Fire in Laundry	4:17	6	62	4:20	4.6	0.9	10	2.4	0.0
sub8_02	Class A Fire in AMR	12:07	1	65	4:15	0.9	0.9	10	4.3	0.2
sub8_03	Class A Fire in AMR and Laundry	16:32	0	63	3:22	0	-1.2	10	1.0	0.1
sub8_04*	Class A & B in AMR	14:35	0	58	6:18	13.2 [3]	4.4 [3]	10	8.7 [3]	-0.1 [3]
sub8_05	Class A & B in AMR	6:35	3	48	12:27	0.8	0.2	10	7.7	0.7
sub8_06	Multi-level Class A in Laundry and Wardroom	8:20	0	147	0:27	2.2	0.0	10	5.7	1.4
sub8_07	Fires 01, 04 and 06	5:54	1	75	1:20	0.8	-3.0	10	7.0	0.8

* Test sub8_04 evaluated Active Desmoking. Column labeled "Rate of Recovery 10 min Period After Initiation of Ventilation" is actually "Rate of Recovery 10 min Period After Fire Reported out."

[1] Rate of Recovery from Fire(s) Reported out to Initiation of Ventilation calculated from appropriate values in Table 3. Visibility value calculated as: ([Vent] - [Fire Out])/Δ Time. Temperature value calculated as: ([Fire Out] - [Vent])/Δ Time.

[2] Rate of Recovery of 10 minute period after initiation of ventilation calculated from appropriate values in Table 3. Visibility value calculated as: ([Vent +10] - [Vent])/10 minutes. Temperature value calculated as ([Vent] - [Vent +10])/10 minutes.

[3] Test sub8_04 evaluated active desmoking. Results calculated from appropriate values in Table 3. Key events changed to conditions as Fire Fighting Initiated [FFI], Initiation of Ventilation [Vent], Fire(s) Reported out [Fire Out], and 10 minute Period Following Fire Reported out [Fire Out + 10].
Rate of Recovery from Initiation of Ventilation to Fire(s) Reported out calculated as: ([Fire Out] - [Vent])/Δ Time.
Rate of Recovery of 10 minute period after Fire(s) Reported out calculated as:([Fire Out + 10] - [Fire Out])/10 minutes.

changed. In sub8_04, the bridge hatch was opened and the L.P. blower was started, exhausting out of the NAV Equipment Room. The supply fan was started once the fire was reported out. In Test sub8_05, the bridge hatch was opened and the L.P. blower started, exhausting out of the NAV Equipment space. Approximately one minute later, the supply fan was started, followed one minute later by the induction fan. Figure 40 shows the quicker recovery of tenable conditions in the Control Room/DC Central when the supply fan was operated as soon as possible. The supply fan created a negative pressure in the Fan Room and more effectively pulled the smoke away from the Control Room/DC Central while cooling the lower platforms. Test personnel in the lower platforms noticed the quicker improvement in conditions when the supply fan was started. The improvement in overall tenability conditions resulting from use of the supply fan was also seen in Tests sub8_06 and sub8_07. Initiating the supply fan temporarily reduced the Control Room visibility, but significantly increased the overall tenability conditions throughout the boat. Figure 48 shows the visibility in CPO/Crew Mess as measured by the ODMs for Tests sub8_06 and sub8_07. The temperatures in CPO/Crew Mess measured at the 1.5-m (5-ft) height for Tests sub8_06 and sub8_07 are shown in Figure 49. The visibility and temperatures, measured in the Torpedo Room, are shown in Figures 50 and 51, respectively.

Active desmoking was conducted in Test sub8_04. As fire fighting was being conducted, the L.P. blower was started, exhausting out of the NAV Equipment room, and the bridge hatch opened. Approximately 6 minutes, 30 seconds later the fires were extinguished. The Man-in-Charge, located on the third platform, reported that as soon as the L.P. blower was started and the bridge hatch opened, conditions improved, making fire fighting easier. The visibility and temperatures measured in the Control Room/DC Central are shown in Figures 36 and 37, respectively. There was no reported increase in fire growth as a result of initiating ventilation. Previous testing [4, 8, 9] has not indicated a significant increase in the burning rate of the fire when mechanical ventilation is initiated. These conclusions are based on fires similar to the fires used in this test series. The effect on increasing the burning rate for larger size fires is unknown.

The ability to surface the boat and open an external hatch in addition to the use of mechanical ventilation has been shown to produce better recovery of tenable conditions. In the 10 minute period following the initiation of ventilation, all four tests showed rates of recovery up to twice that of the first three tests where the use of external hatches for ventilation purposes was not possible. Active desmoking was also shown to produce a significant rate of recovery for tenability conditions in the Control Room before the fire was extinguished. By being able to initiate ventilation to remove smoke prior to the extinguishment of the fire, tenability threshold limits were exceeded for the shortest amount of time. Fire fighting conditions were also improved, allowing quicker access to the fire and quicker extinguishment of the fire. No significant fire growth was noted by test personnel during active desmoking, but a ventilation alignment which significantly fuels the fire with fresh air should not be used since this would outweigh the need to improve conditions for the fire fighters.

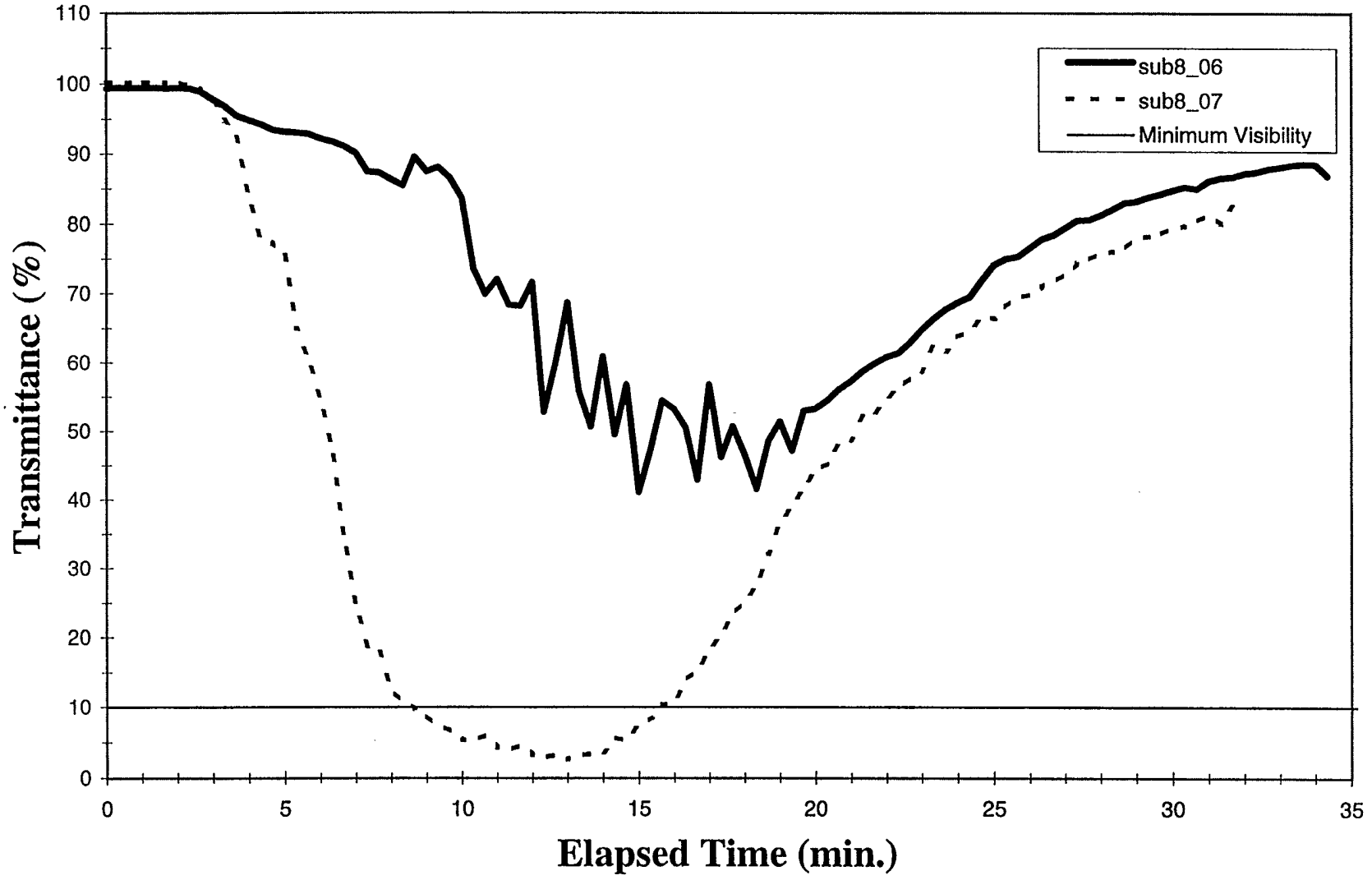


Fig. 48 – CPO/Crew Mess visibility (1.5 m ODMs), Test sub8_06 and _07

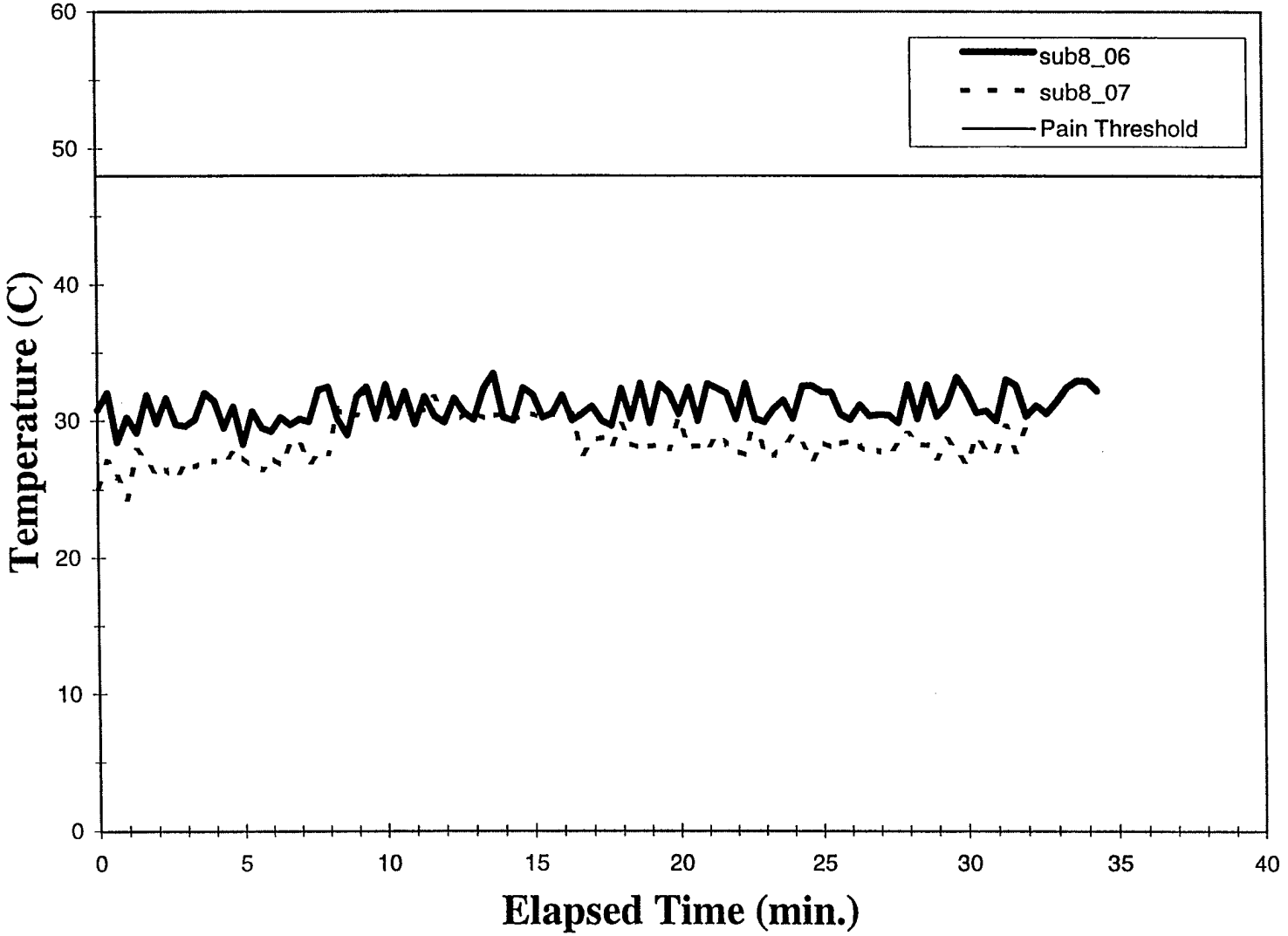


Fig. 49 – CPO/Crew Mess temperatures (1.5 m TC's), Test sub8_06 and _07

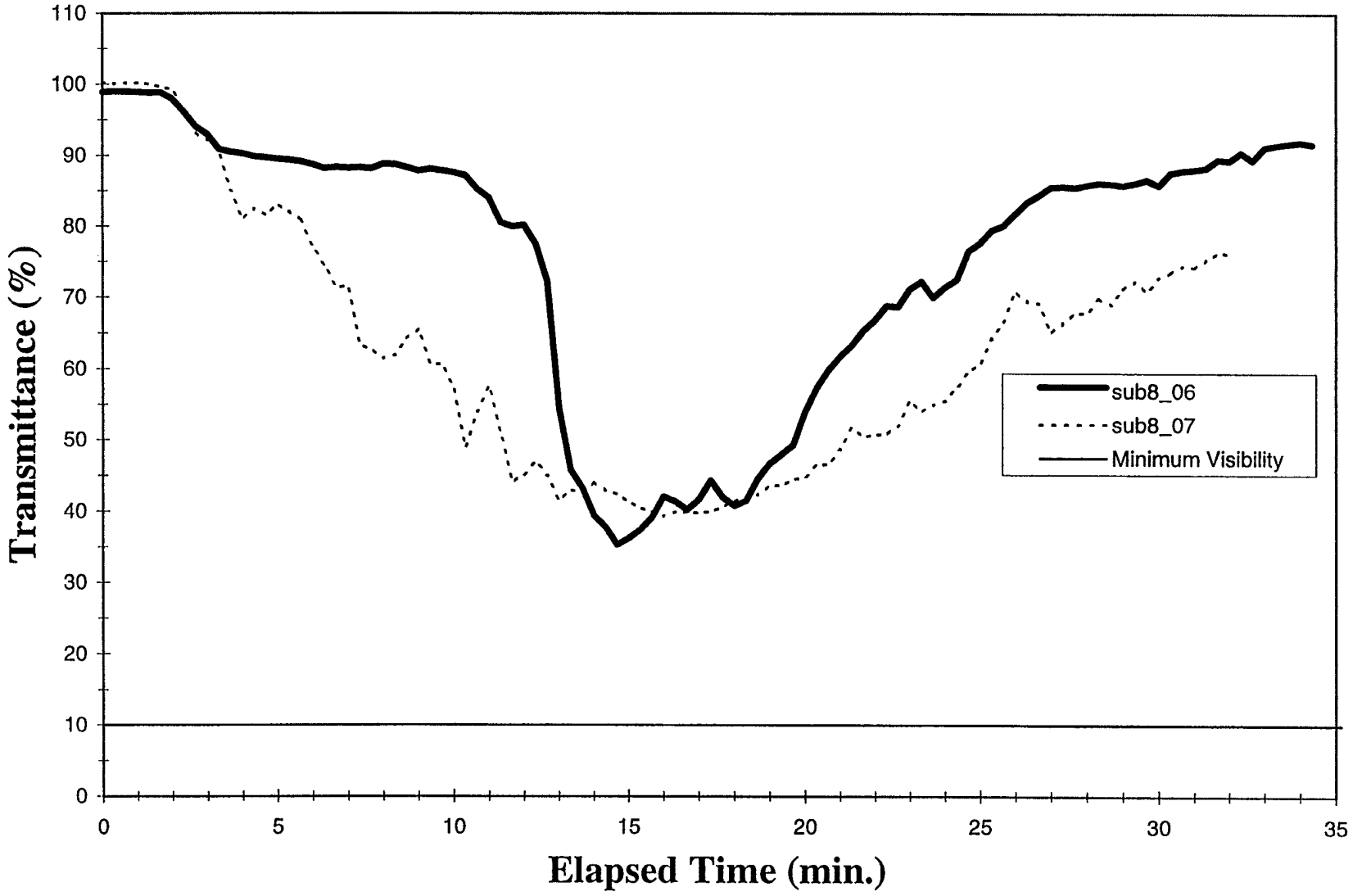


Fig. 50 – Torpedo Room visibility (1.5 m ODMs), Test sub8_06 and _07

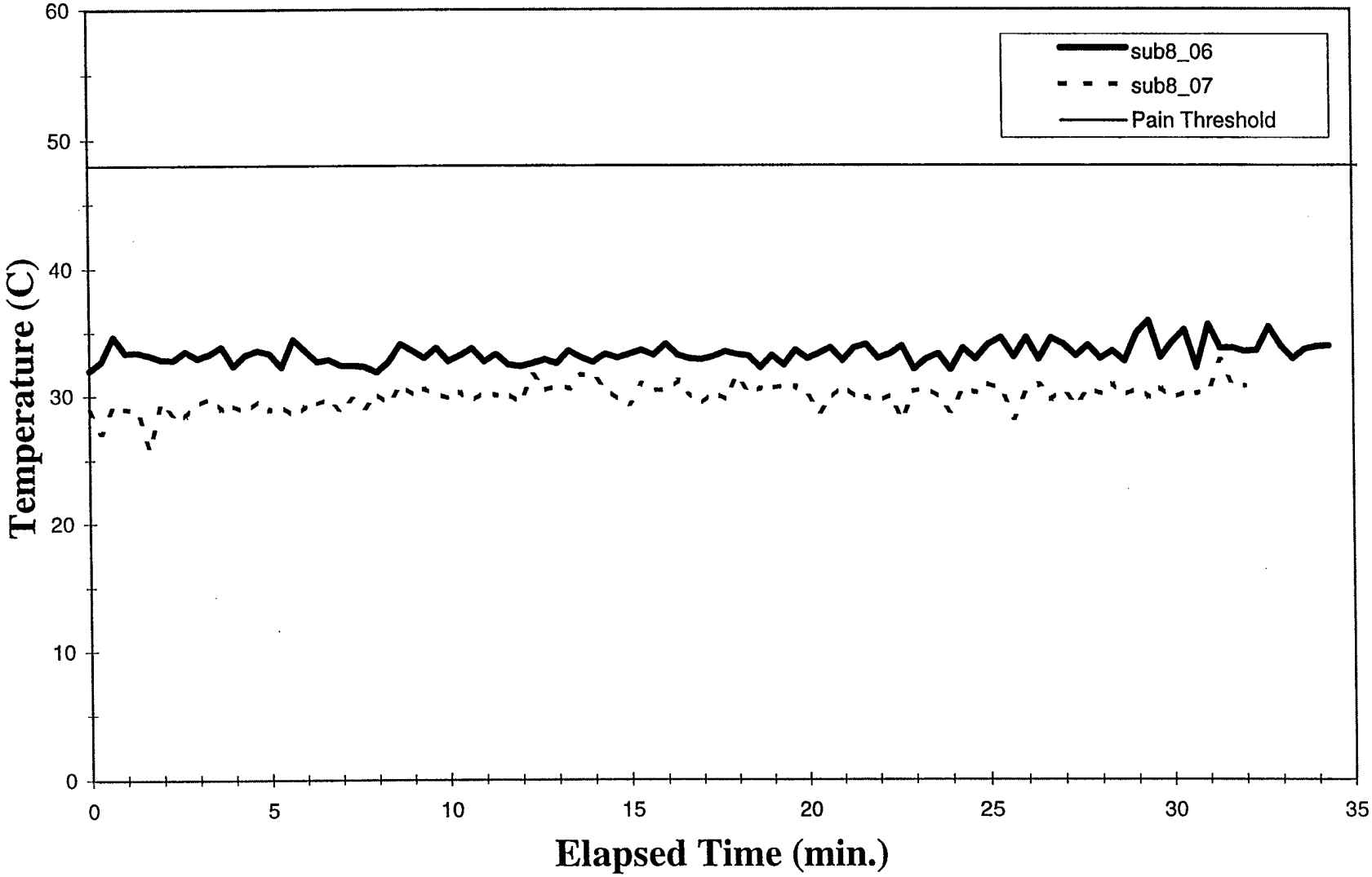


Fig. 51 – Torpedo Room temperatures (1.5 m TC's), Test sub8_06 and _07

14.0 DEBRIEFING FINDINGS

Based on the subjective data collected during the post-test debriefs and the data provided by the instrumentation, the following trends and issues were identified:

14.1 Fire Fighting Equipment and Tactics

1. Requiring the Watchstander and the Rapid Response Team to expend two portable CO_2 extinguishers regardless of the fire type for initial fire attack is not the best requirement. Portable extinguisher use should be based upon the initial fire evaluation by the Watchstander and Rapid Response Team.

2. The use of a PKP extinguisher by the Watchstander and Rapid Response Team significantly knocked down the fire and required the arriving hose team to only extinguish remaining fire/hot embers and standby as reflash watch instead of conducting actual fire fighting.

3. The use of the 1.9-cm (0.75-in.) diameter hose reel permitted the Rapid Response Team to apply water to the fire prior to the arrival of Hose Team 1 on scene while the fire was still in its incipient/early growing stages. Collateral damage and water usage were significantly reduced when compared to use of the 3.8-cm (1.5-in.) diameter hose.

14.2 Protective Equipment

1. The use of Chem Lights to illuminate EAB manifolds should be implemented on all submarines. The Chem Lights clearly distinguished the location of the EAB manifold in a dark, smoky environment.

2. Placing Chem Lights on the Man-in-Charge, Hose Team leaders/NFTI operators and other key personnel should be practiced. This permits easy recognition of these key personnel in a smoky environment by arriving personnel.

3. Flashlights and battle lanterns, rigged with red lenses, penetrated heavy smoke and allowed personnel improved visibility on the fire scene [21].

4. The option of a manual start on the OBA should be provided. This permitted longer on-scene time and saves the candle for egress from the scene when the 30 minute timer sounds or for emergency situations, if required.

5. Permitting personnel only 30 minutes on an OBA canister significantly reduced the total working capacity of a single OBA canister. SHADWELL personnel

routinely used a single canister for 90 minutes or longer. A re-evaluation of the 30 minute time limit should be undertaken.

6. It is easy for a fire fighter to change out OBA canisters in a smoky/contaminated environment without breathing in smoke and other contaminants. Requiring change-out areas be smoke free may not be feasible in a fire situation.

7. The one-piece FFE is very difficult to don, requires assistance from another person and drastically restricts the freedom of movement of the fire fighter. The transition to a two-piece ensemble (similar to civilian fire fighting gear) should be investigated.

8. Quick change out of personnel from the fire compartment and removal of personnel in FFEs to cooler "safe" areas when not required greatly reduced the heat stress on the fire fighters.

14.3 Ventilation Tactics

1. Pre-staging the lower bridge hatch to the open position prior to opening the main bridge hatch is not recommended. By pre-staging the lower bridge hatch, the access trunk would accumulate hot gases and become very hot. This would make opening the main hatch very difficult.

15.0 RECOMMENDATIONS

Based on the findings and conclusions outlined above, the following recommendations have been developed:

1. Revise the current ventilation doctrine [3] to provide guidance and procedures for the use of the Control Room Sweep for active desmoking while underway. Include the addition of the supply and induction fans to the Control Room Sweep for post-fire desmoking.

2. A manned test series should be conducted to evaluate submarine fire fighting organization and procedures while in port, which is when most severe submarine fires have occurred.

3. Conduct a series of tests to better quantify the improvements in tenability conditions on the lower platforms when the supply fan is operated as reported by test participants during this test series. Both periscope depth and surfaced scenarios should be evaluated. Evaluate the effects of operating the supply fan during active desmoking on the burning rate of the fire.

4. Prepare training guidance to Fleet personnel on the results of these tests and the ventilation guidance developed.

5. Consider incorporating the fire fighting equipment and tactics, and protective equipment changes as identified from this test series and implement in current doctrine [3]. In particular, the effectiveness of the 1.9-cm (0.75-in.) hose reels should be considered as an alternative or supplemental to existing fire fighting equipment (i.e., 3.8-cm (1.5-in.) hand lines).

6. Consider conducting a test program to evaluate the performance of a portable ABC multipurpose dry chemical extinguisher on representative Class A and B fires applicable to submarine fire scenarios. Also consider evaluating the feasibility of replacing existing portable extinguishers with a suitable, all-purpose ABC extinguisher.

7. Re-evaluate the state-of-the-art in portable fire extinguisher technology to determine if existing or near-future technology can improve extinguisher design (e.g., reduce current weight of CO_2 extinguishers using composite bottles) and/or fire fighting effectiveness.

8. Consider conducting a test program to evaluate the ventilation alignment on an Ohio Class (Trident ballistic missile) submarine utilizing the SHADWELL/688 test mock-up with required modifications to simulate the ventilation system, compartment layout, and ventilation procedures.

9. Consider evaluating the tenability data in this and previous SHADWELL 688 testing to determine if current gas-free engineering tactics, doctrine and procedures can be modified for post-fire conditions.

16.0 ACKNOWLEDGMENTS

Thanks are extended to the safety team members: D. Satterfield (NAVSEA O3G), and C. Labucki; to MMCS (SS) Robert Rayburn for his assistance in organizing the test participants, for insuring realism was attained in the set up of the test space, and for imparting his knowledge of submarine operating procedures into the test procedure; and to the crew of the ex-SHADWELL; in particular Russell Robertson, Karl Krueger, Manton Smith, Hung Pham, Eric Chambers and Steve Luckie; for their support in getting the facility ready under a compressed time schedule and help during test week.

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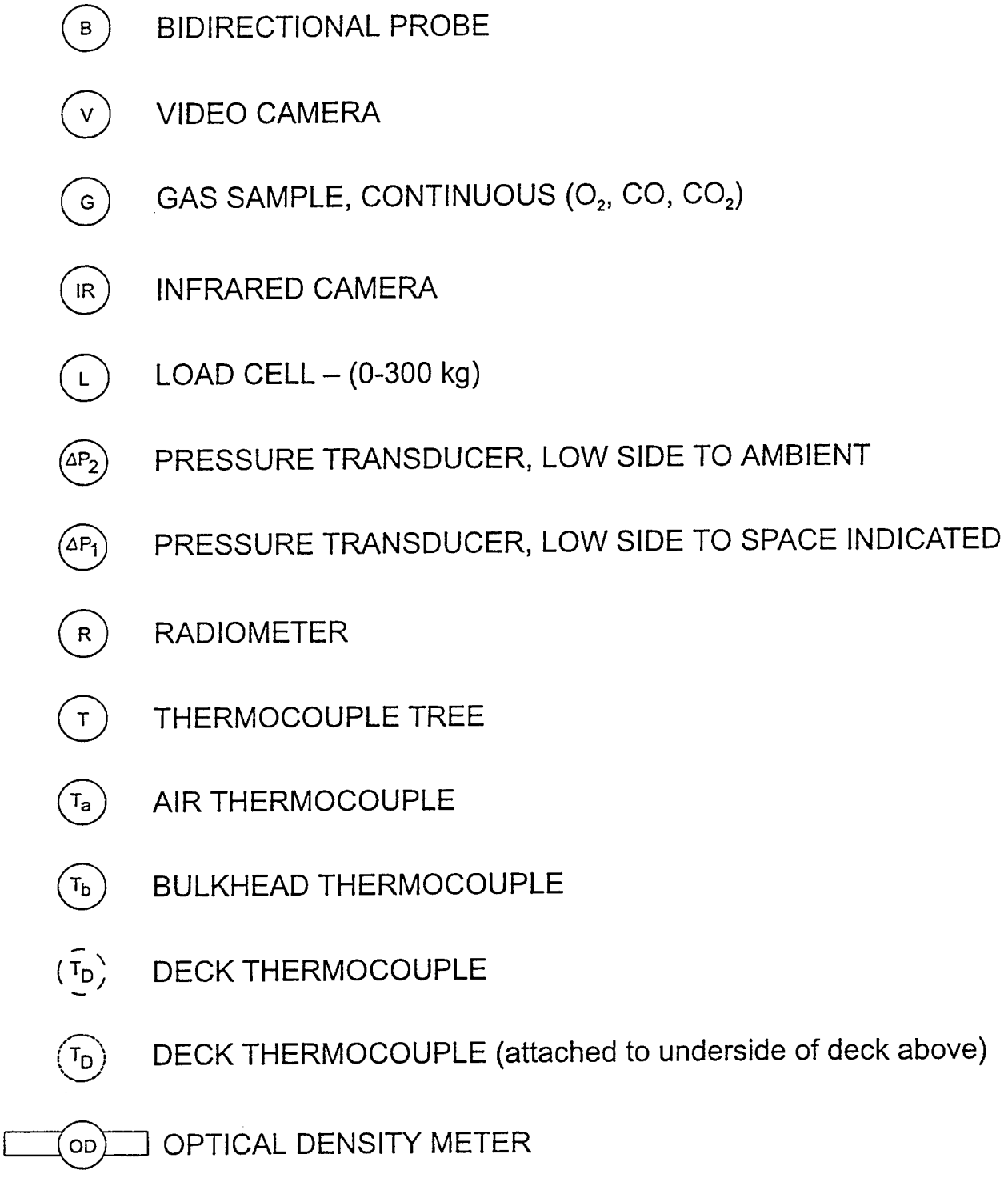
Appendix A

Instrumentation Drawings

INSTRUMENT KEY



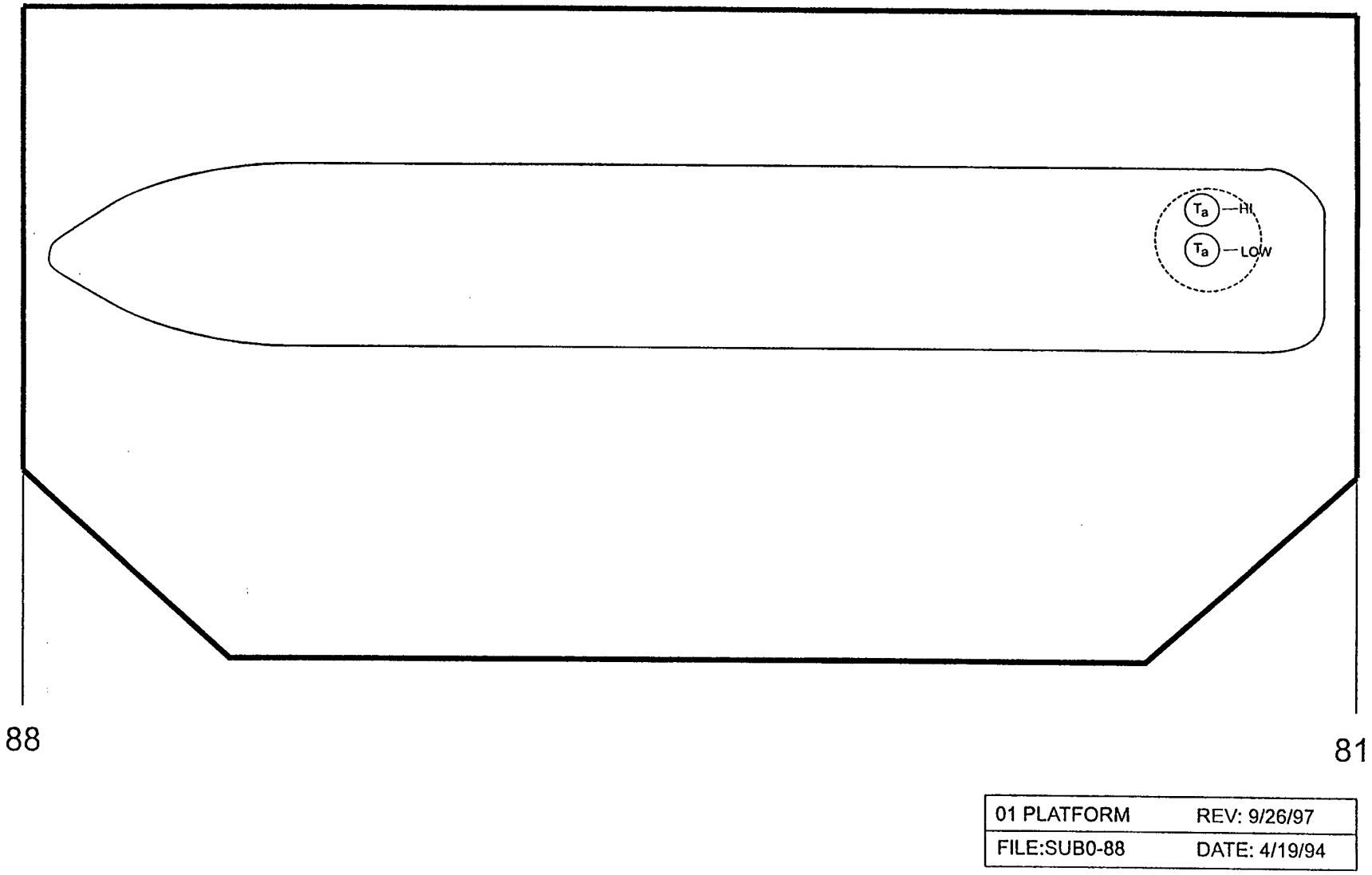


Fig. A1 – Sail Area (Bridge Access Trunk)

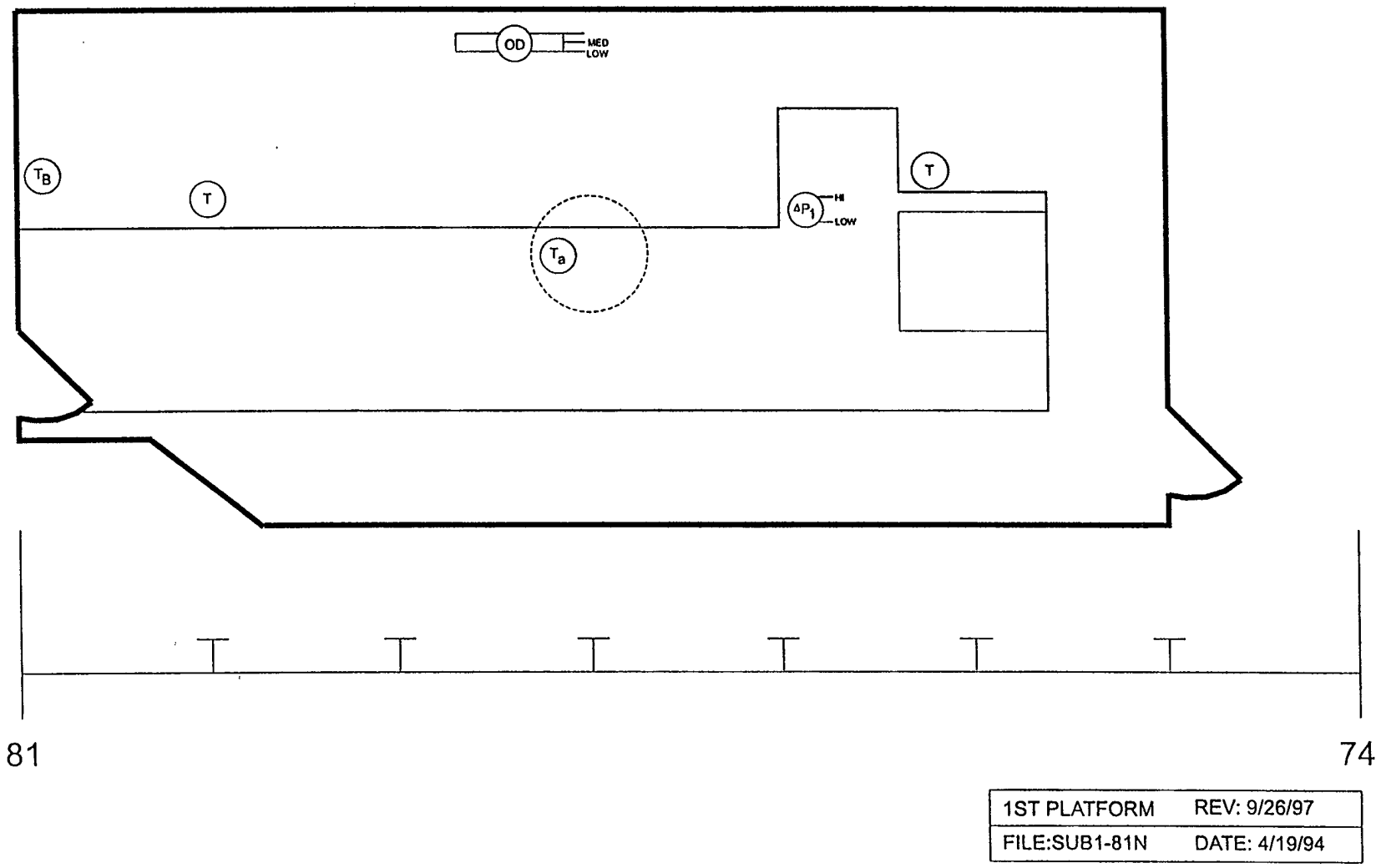


Fig. A2 – Combat Systems 1-74-2

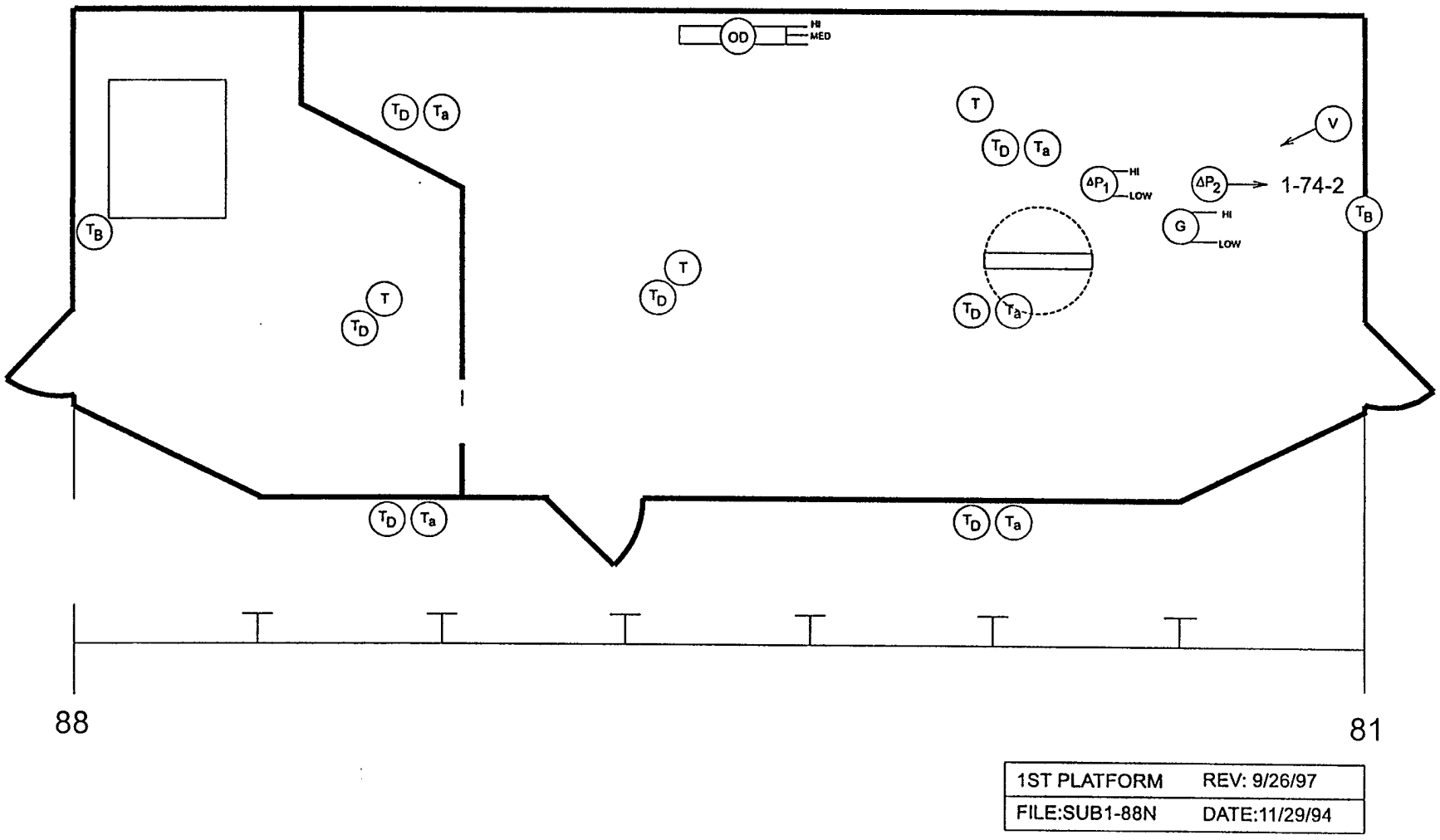


Fig. A3 – Control Room

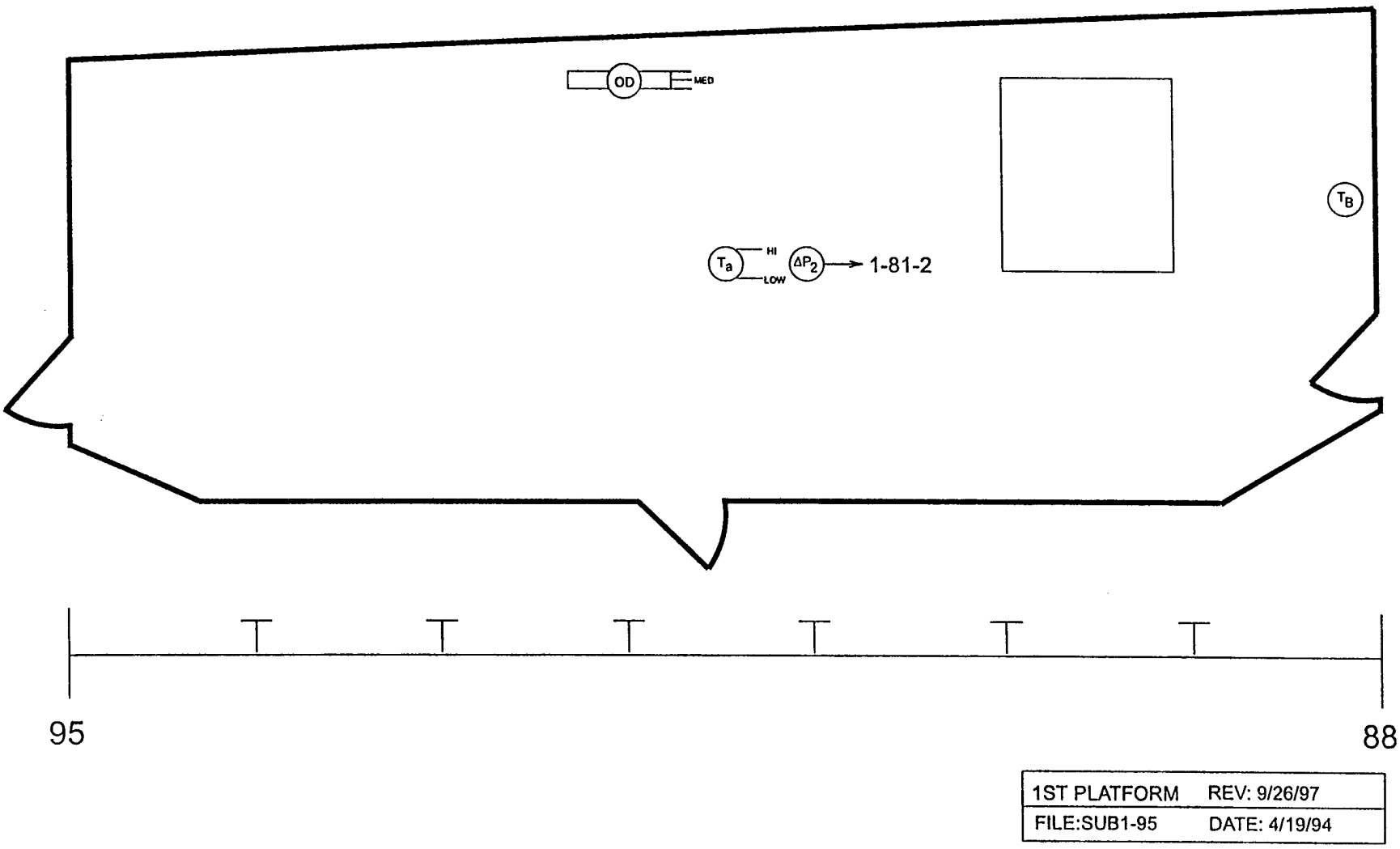


Fig. A4 – Fan Room instrumentation layout

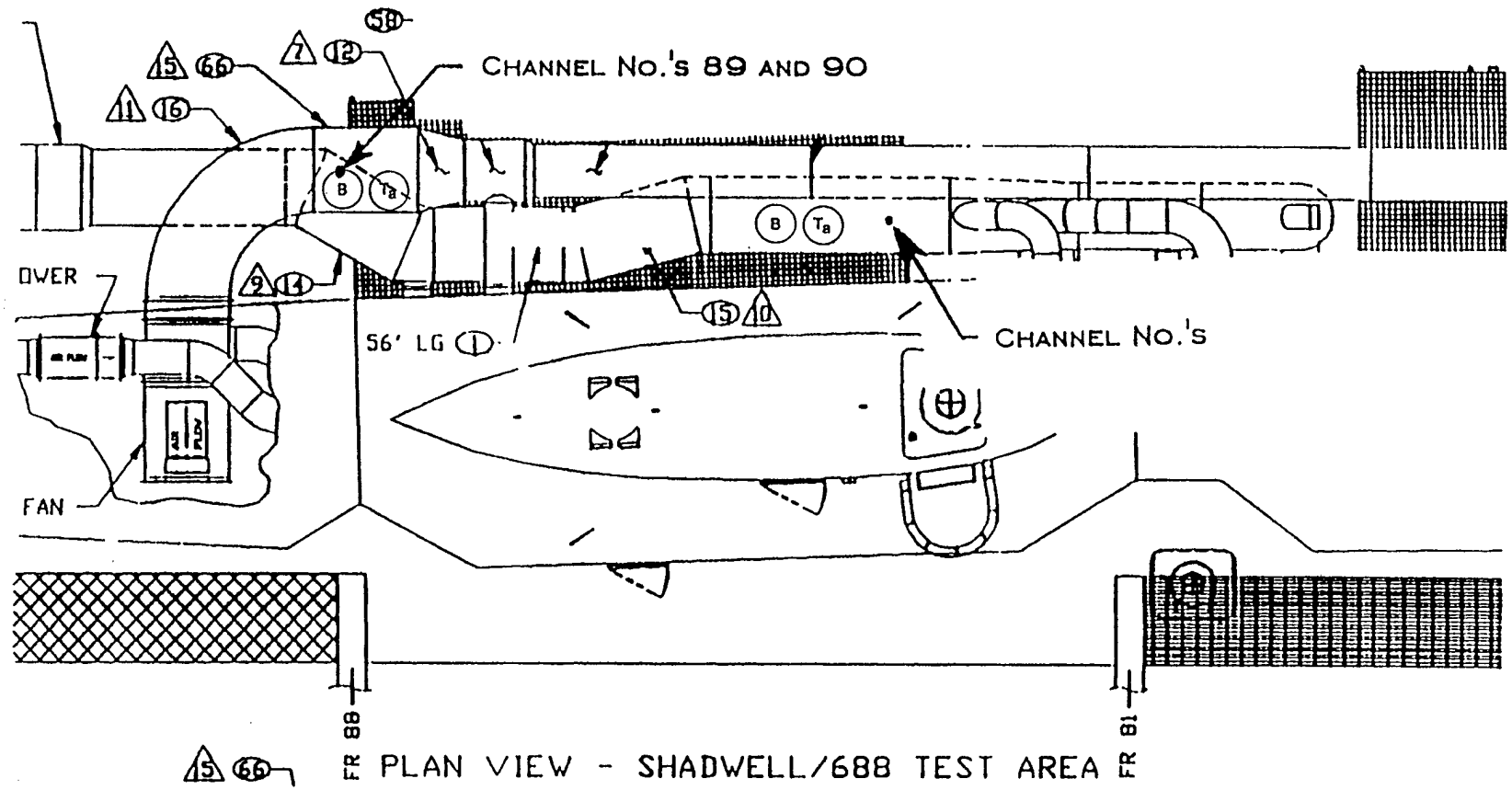
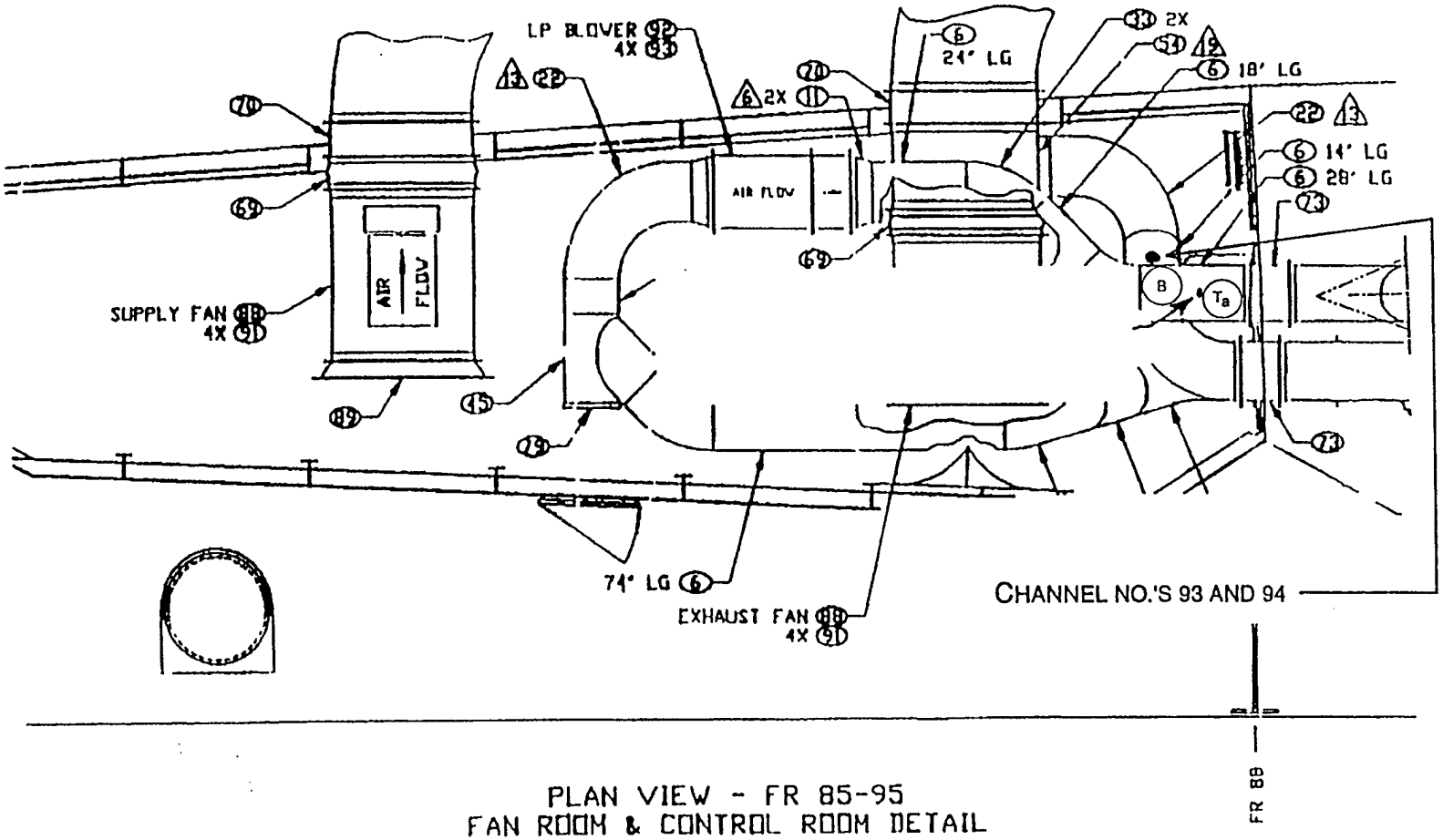


Fig. A5 – Supply and Exhaust Ventilation Ducting instruments



PLAN VIEW - FR 85-95
FAN ROOM & CONTROL ROOM DETAIL

Fig. A6 – L.P. Blower Ducting instruments

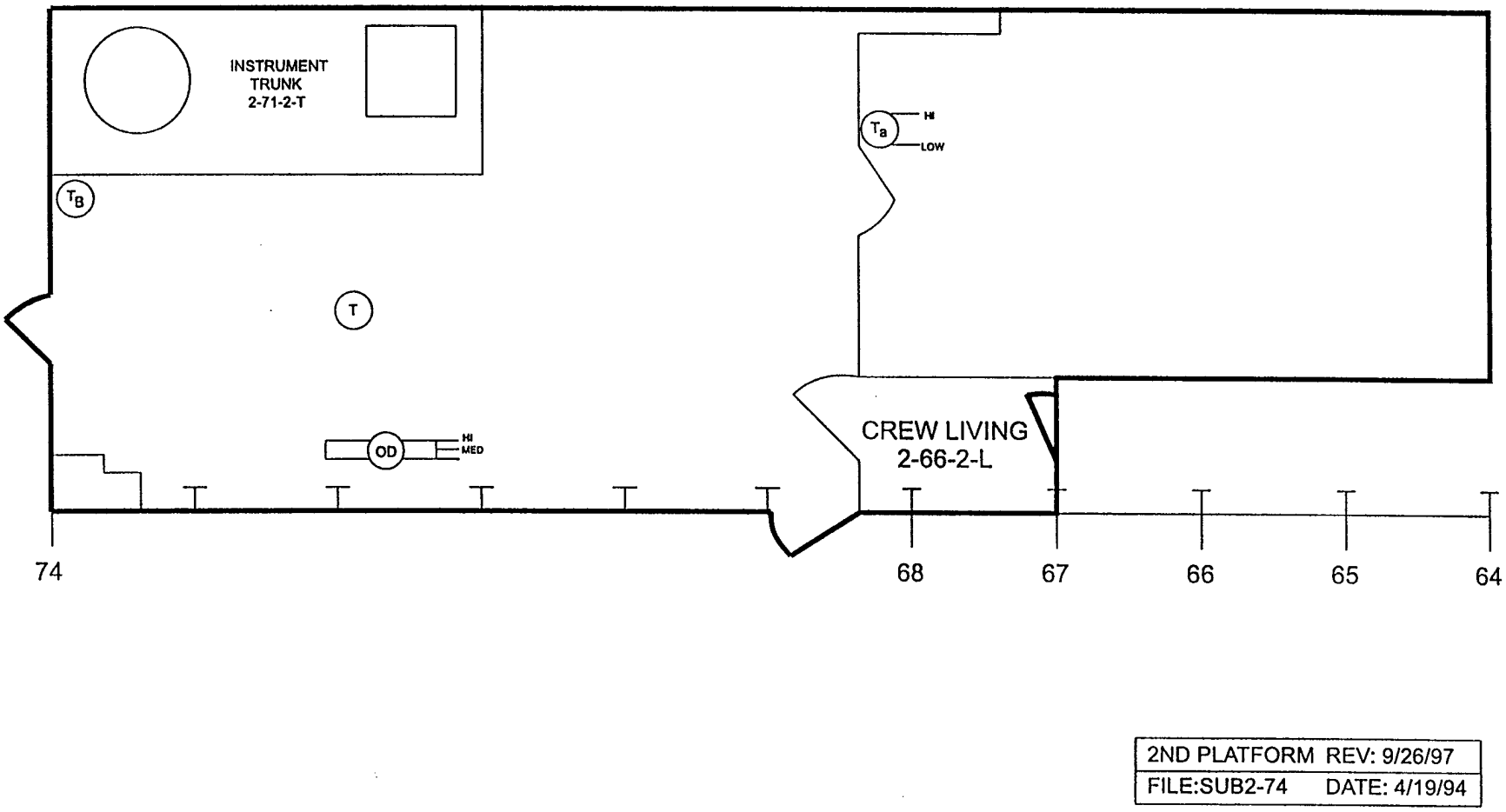


Fig. A7 – CPO Living Quarters instrumentation layout

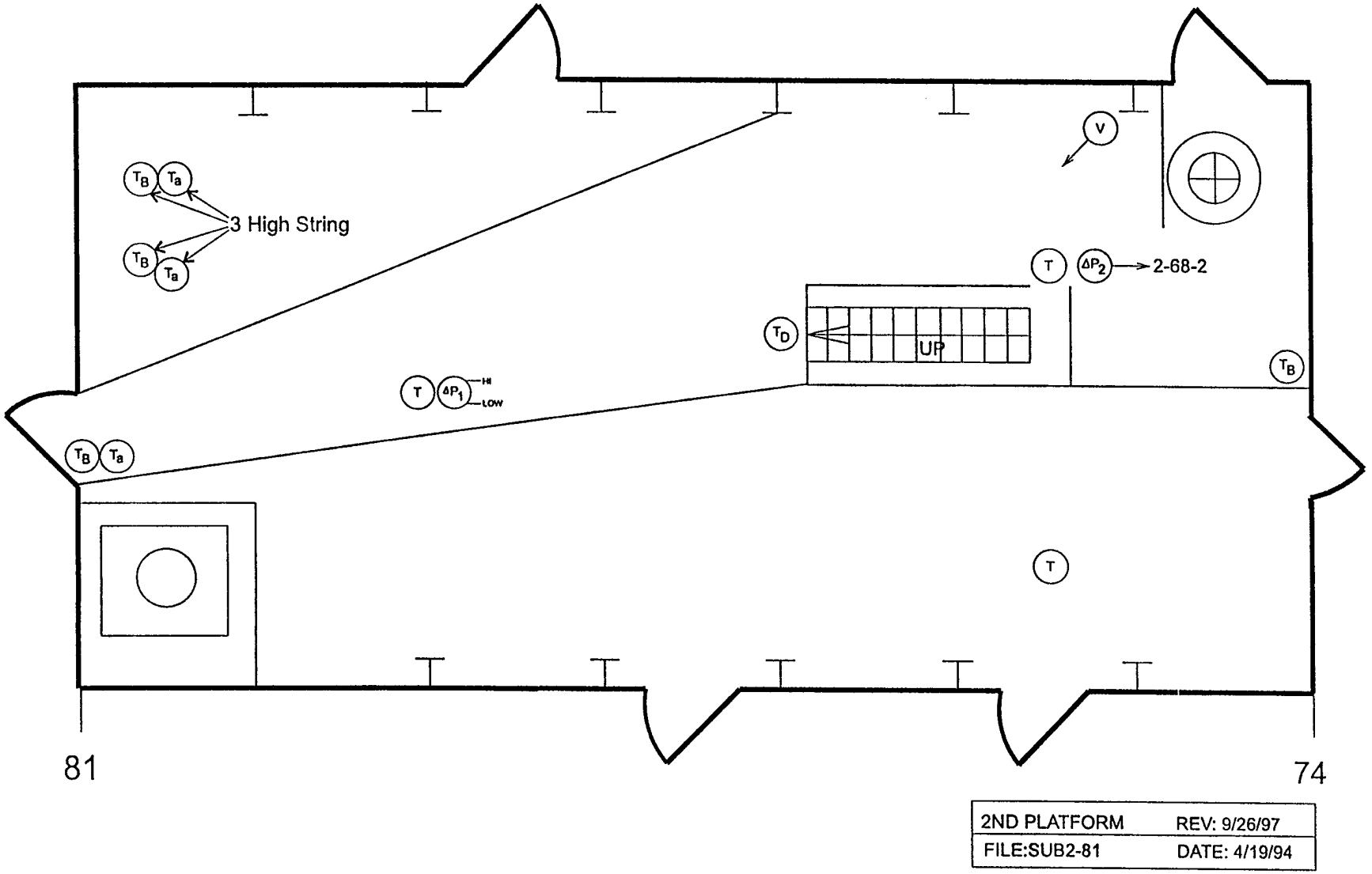


Fig. A8 – Crew Living instrumentation layout

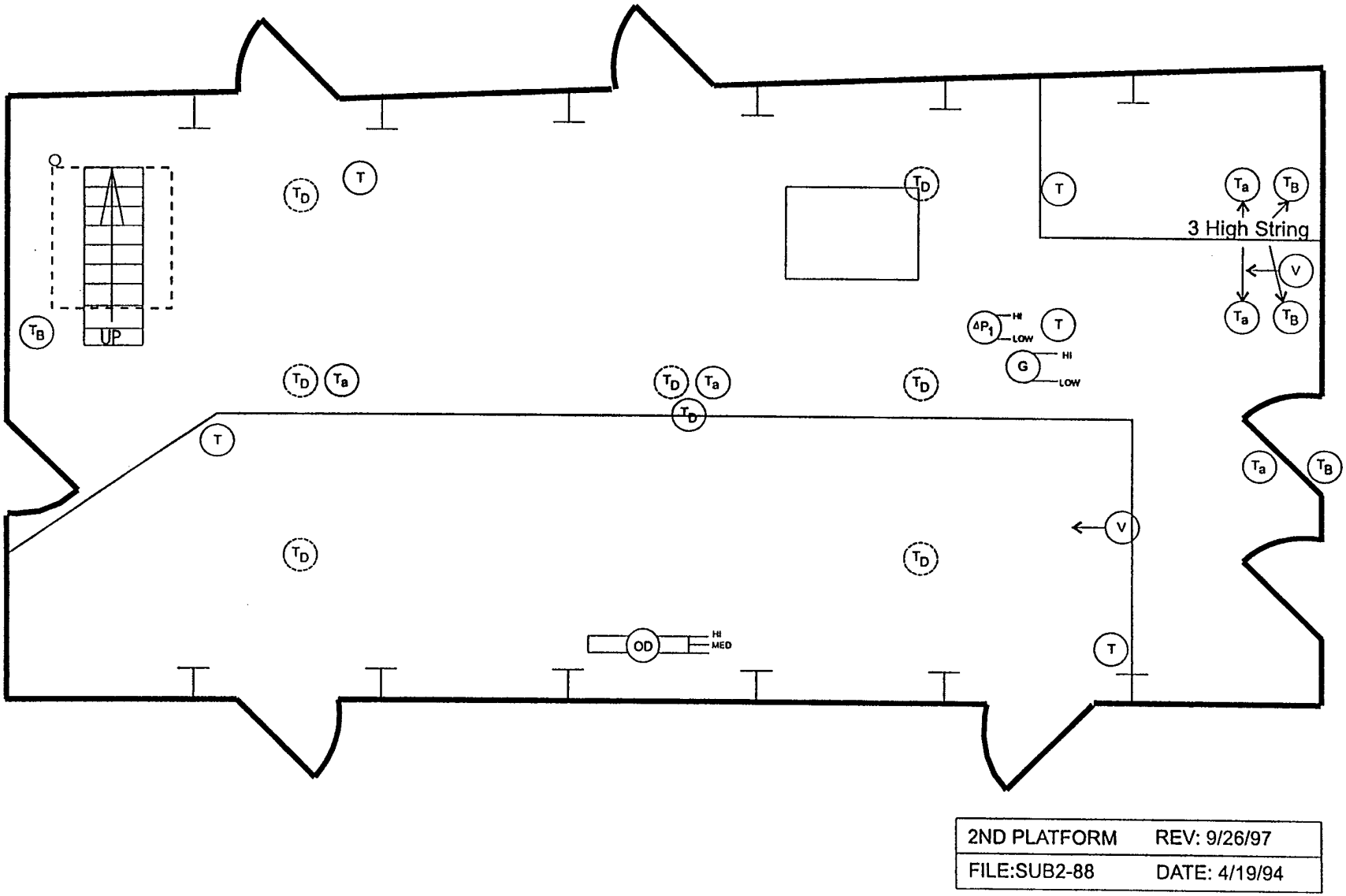


Fig. A9 – Wardroom instrumentation layout

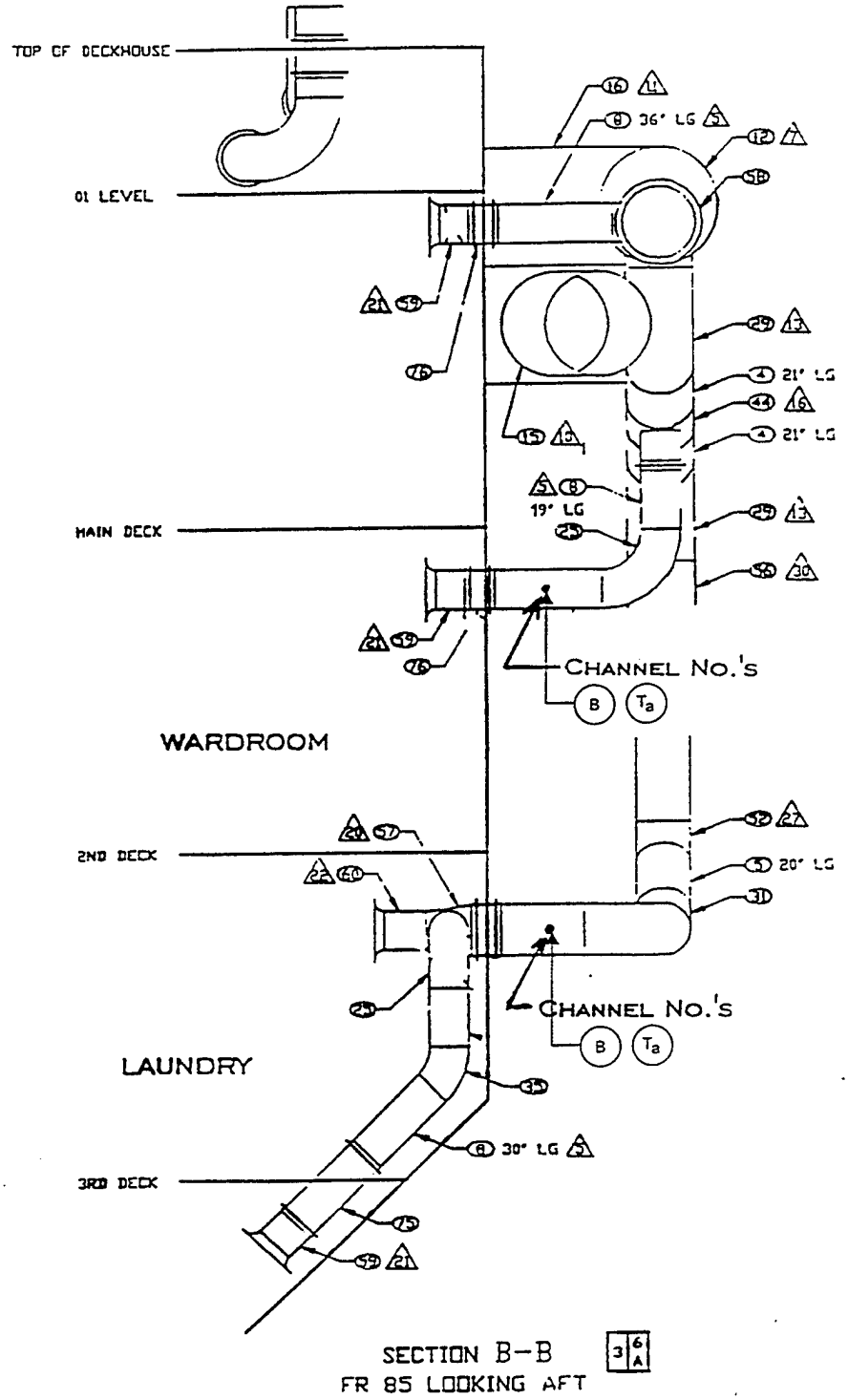


Fig. A10 – Exhaust Ventilation Ducting instruments

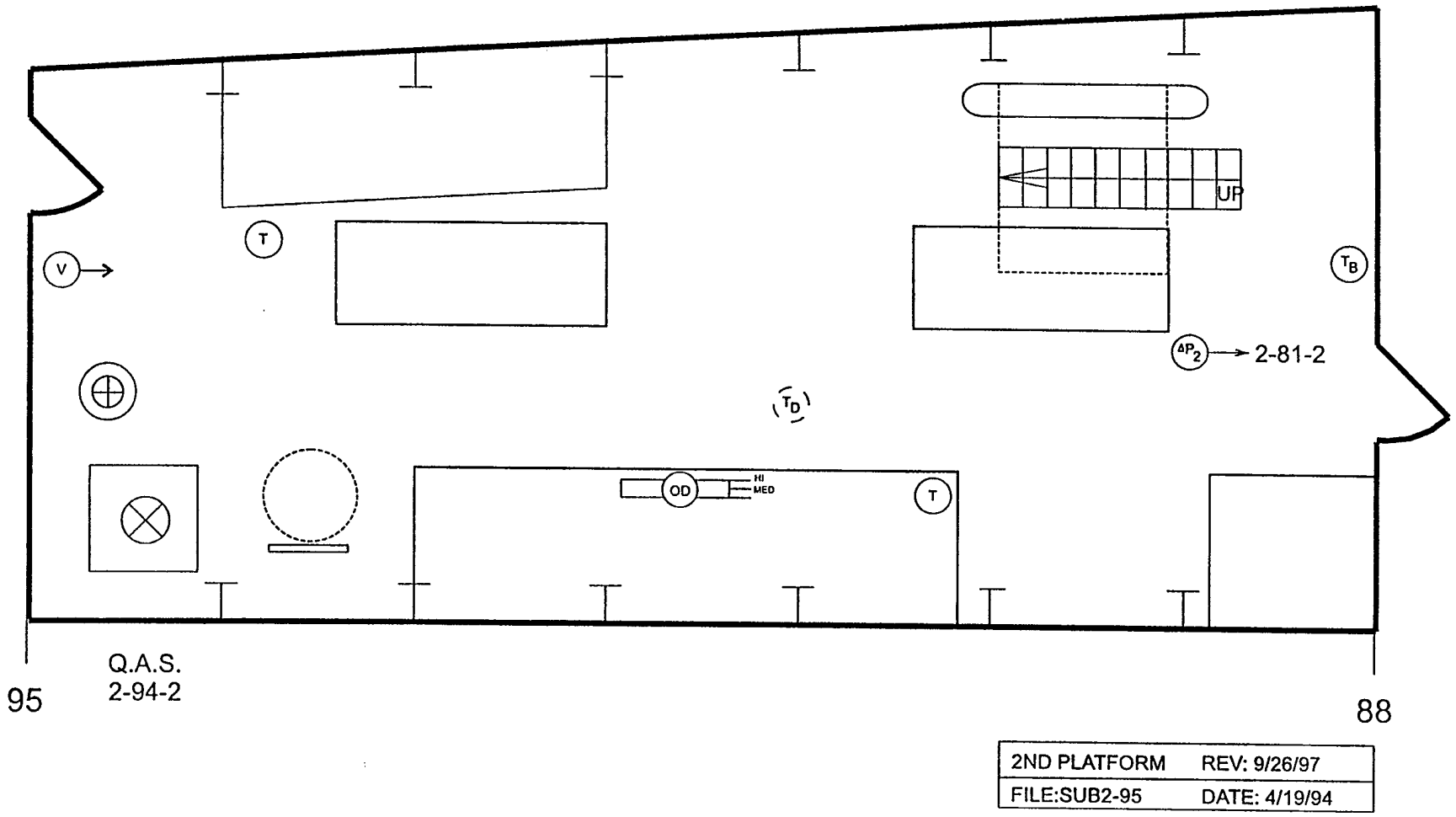


Fig. A11 – CPO/Crew Mess Room

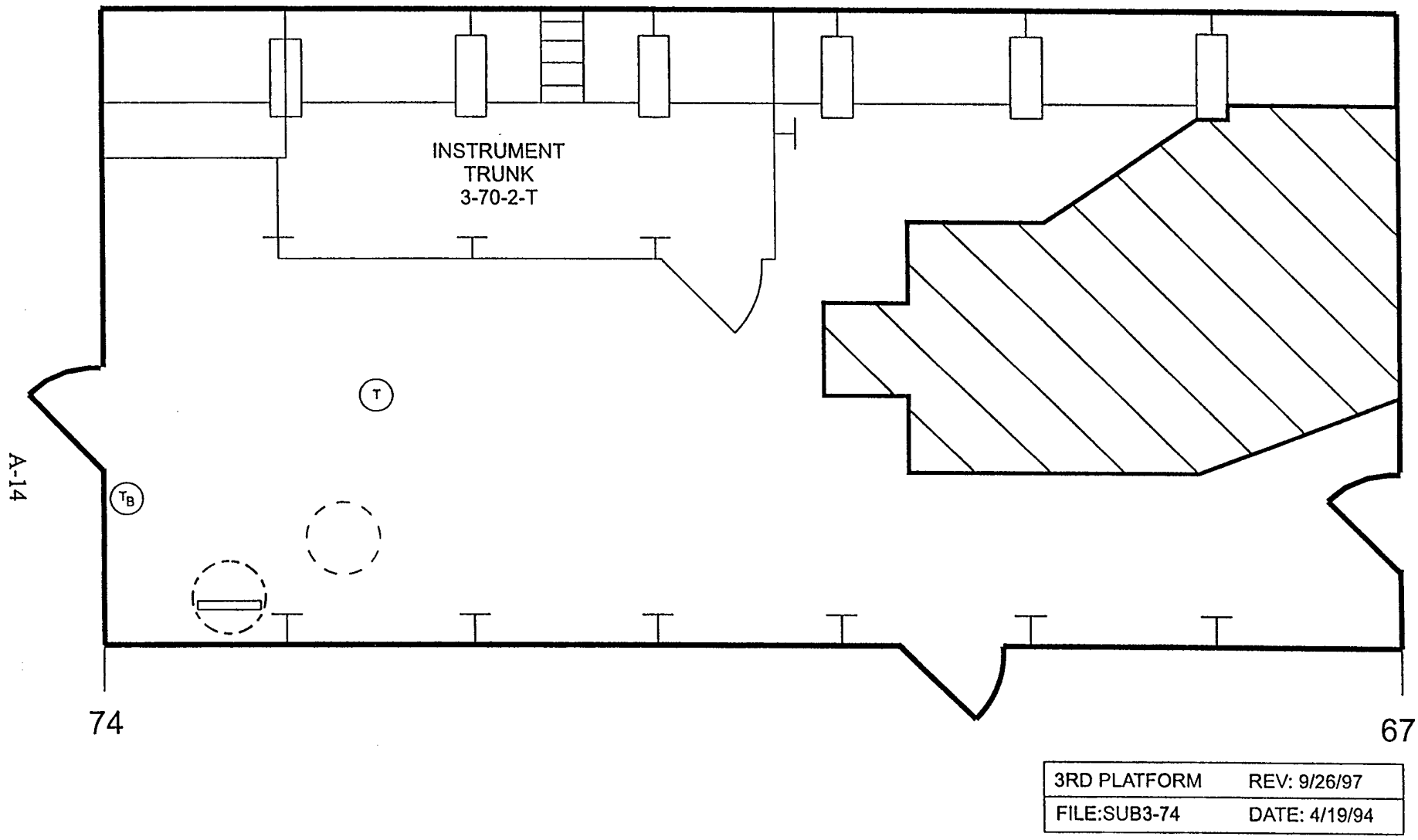


Fig. A12 – Store Room instrumentation layout

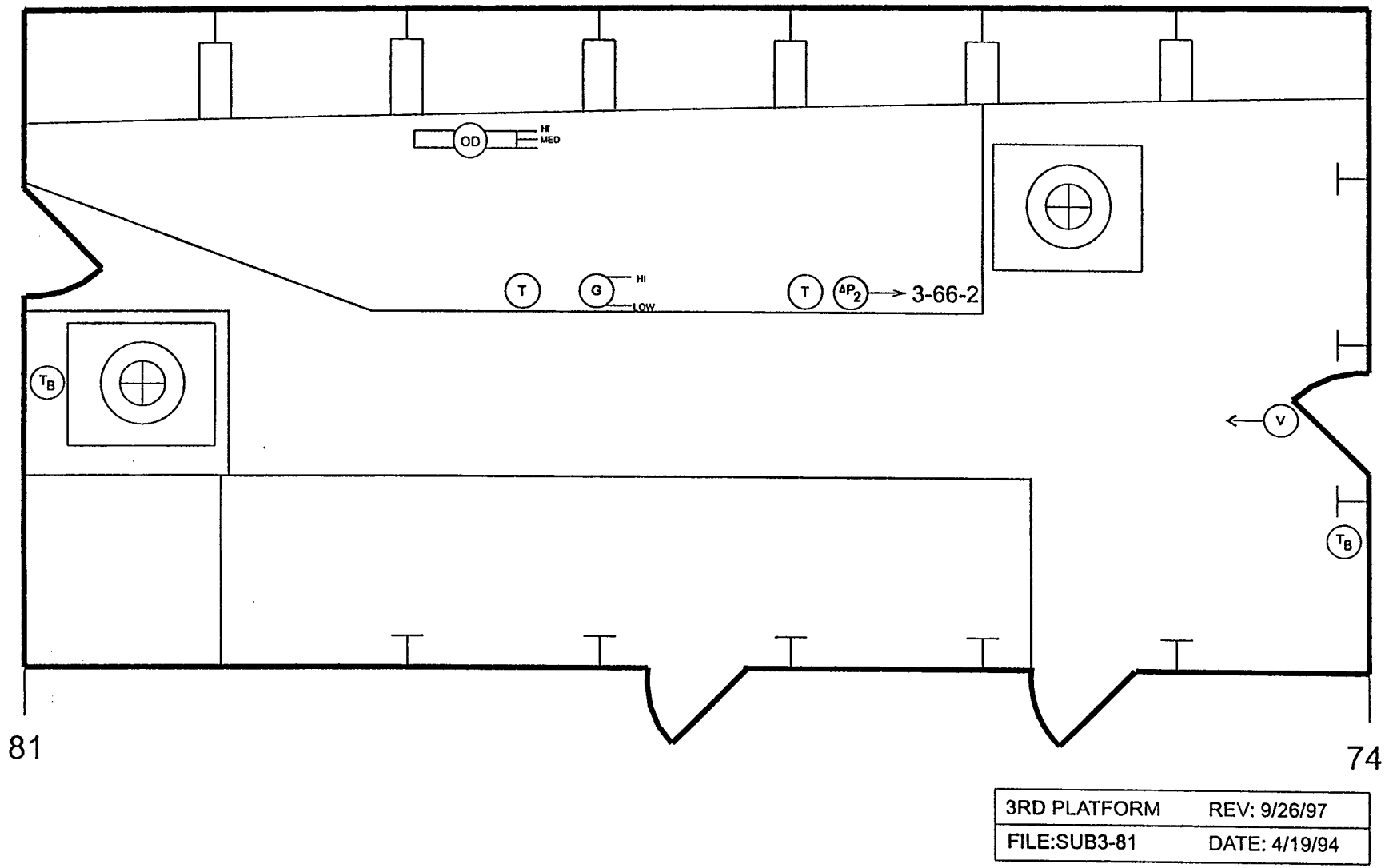


Fig. A13 – Torpedo Room instrumentation layout

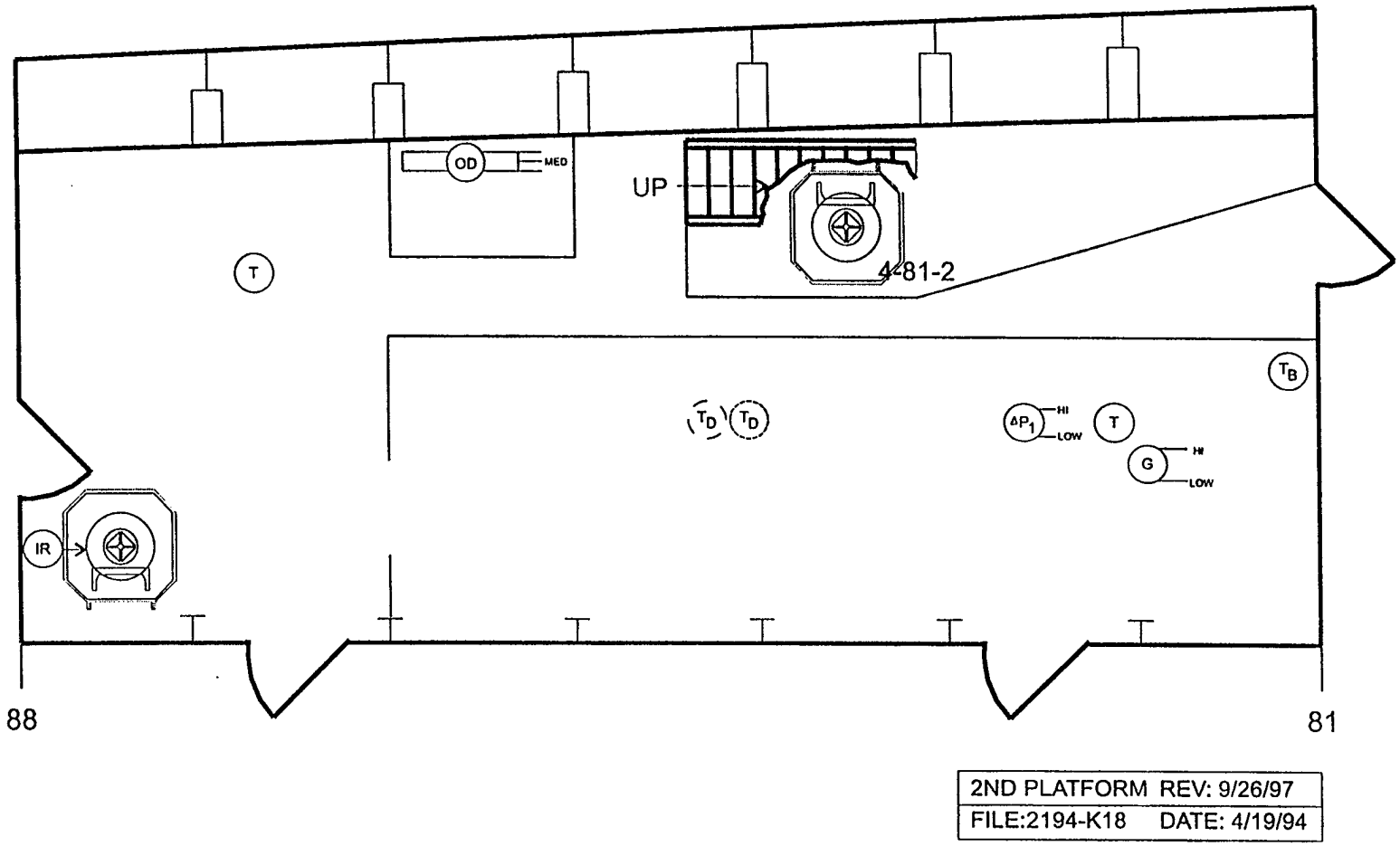


Fig. A14 – Laundry instrumentation layout

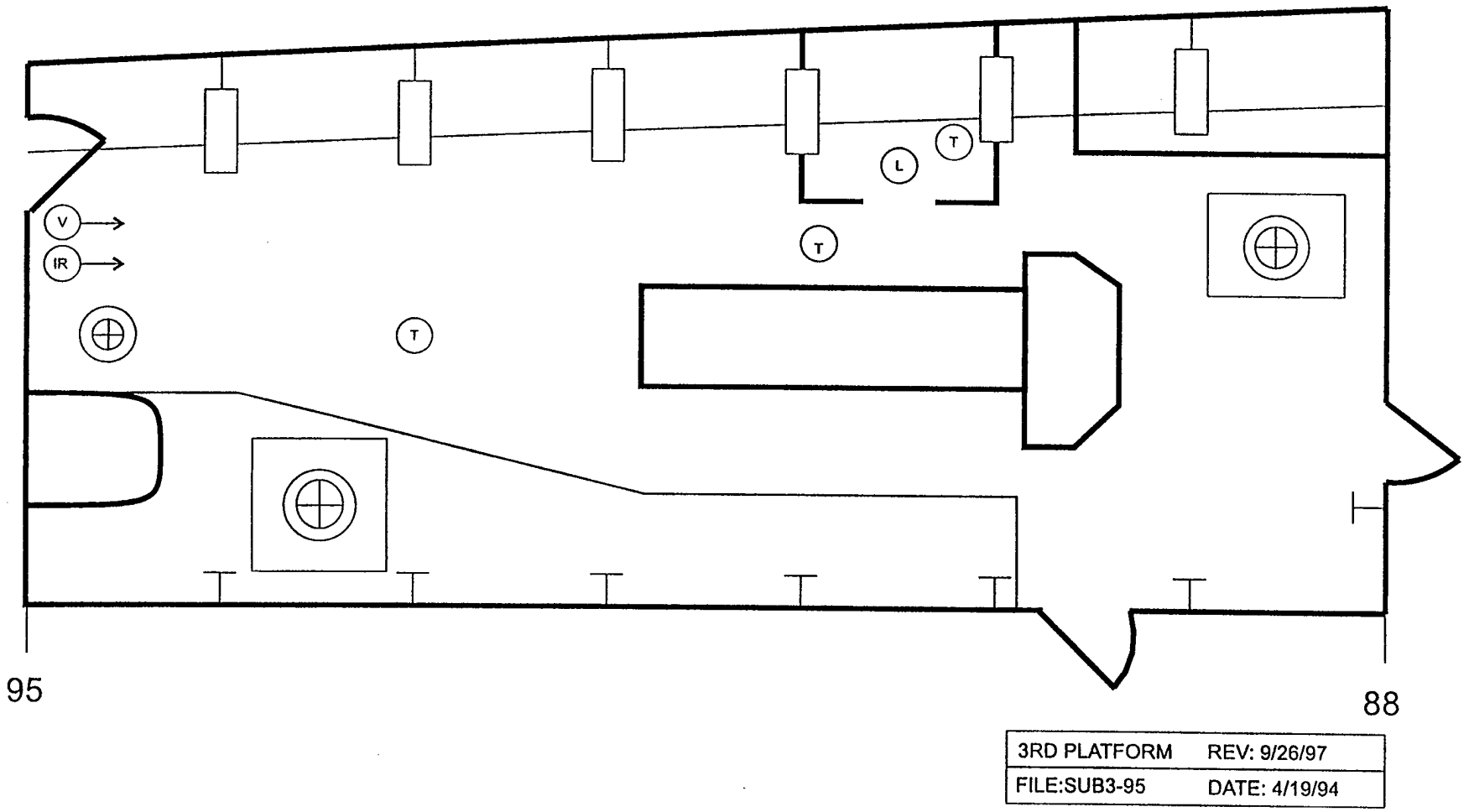
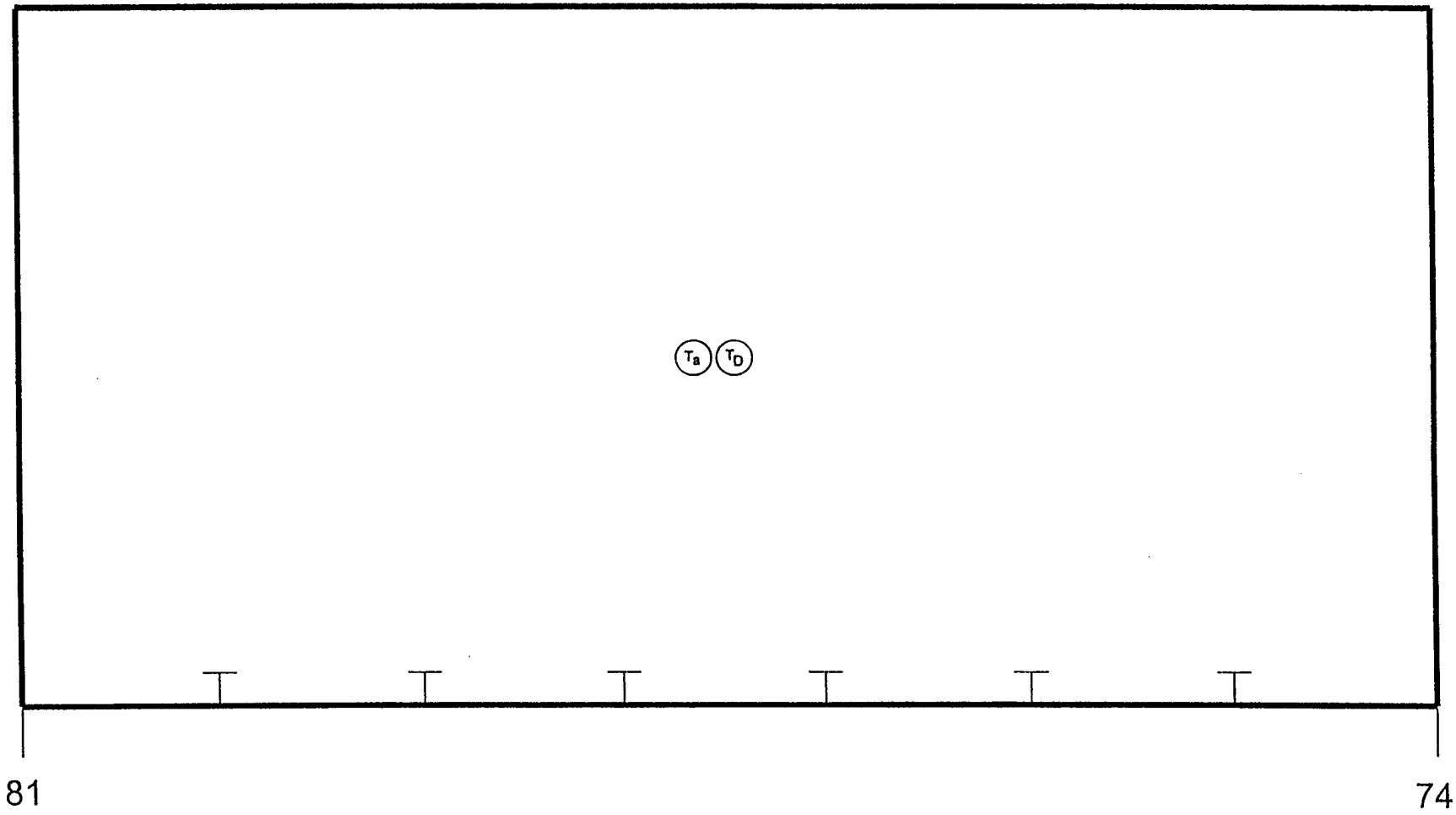


Fig. A15 - AMR

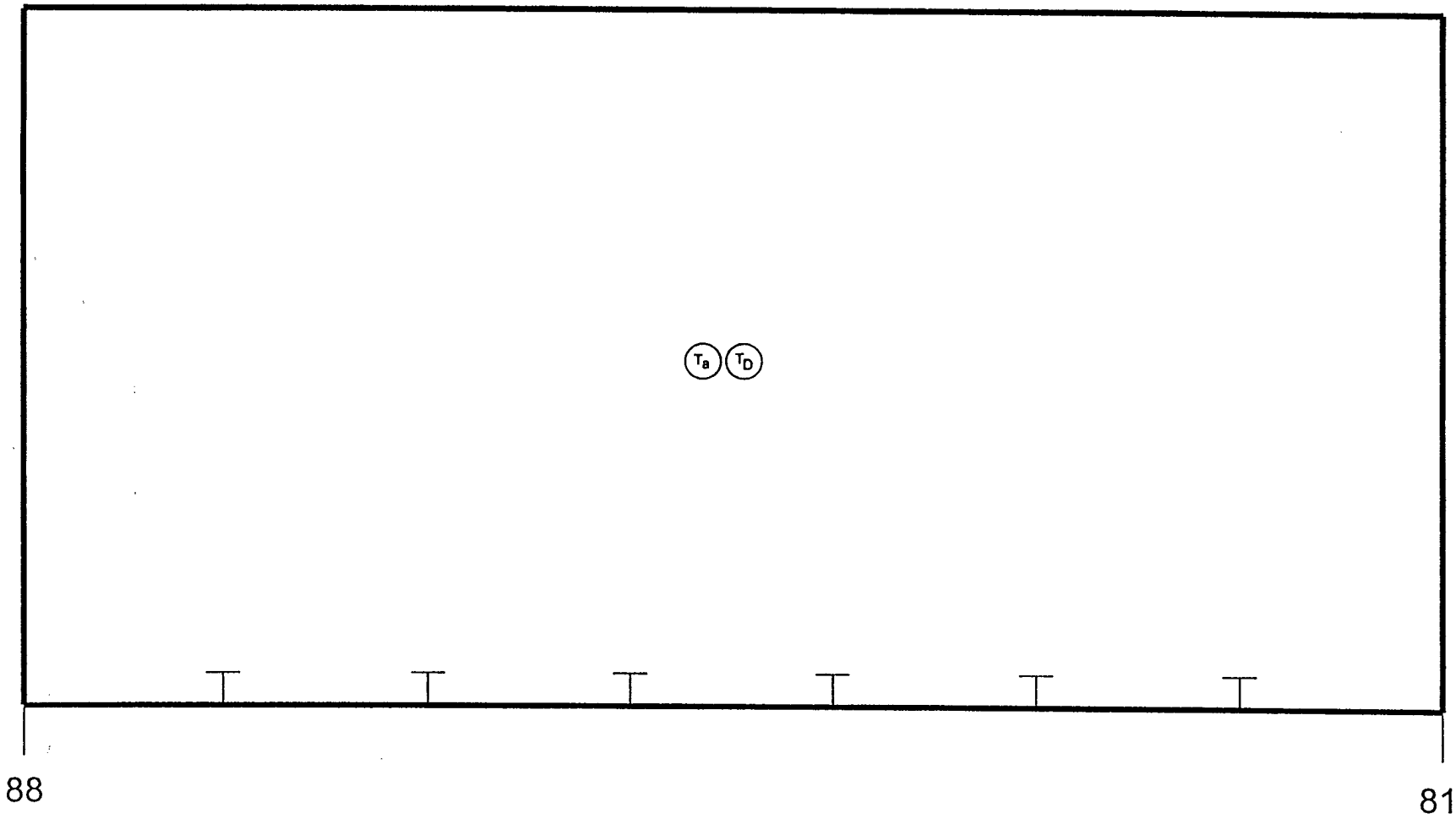
NOTE: THIS IS AN OUTLINE OF THE OVERHEAD;
ACTUAL TANK SPACE TAPERS DOWN



4TH PLATFORM	REV: 9/26/97
FILE:SUB4-74	DATE: 4/19/94

Fig. A16 – Bilge instrumentation layout

NOTE: THIS IS AN OUTLINE OF THE OVERHEAD;
ACTUAL TANK SPACE TAPERS DOWN



4TH PLATFORM	REV: 9/26/97
FILE:SUB4-81	DATE: 4/19/94

Fig. A17 – Battery Compartment instrumentation layout

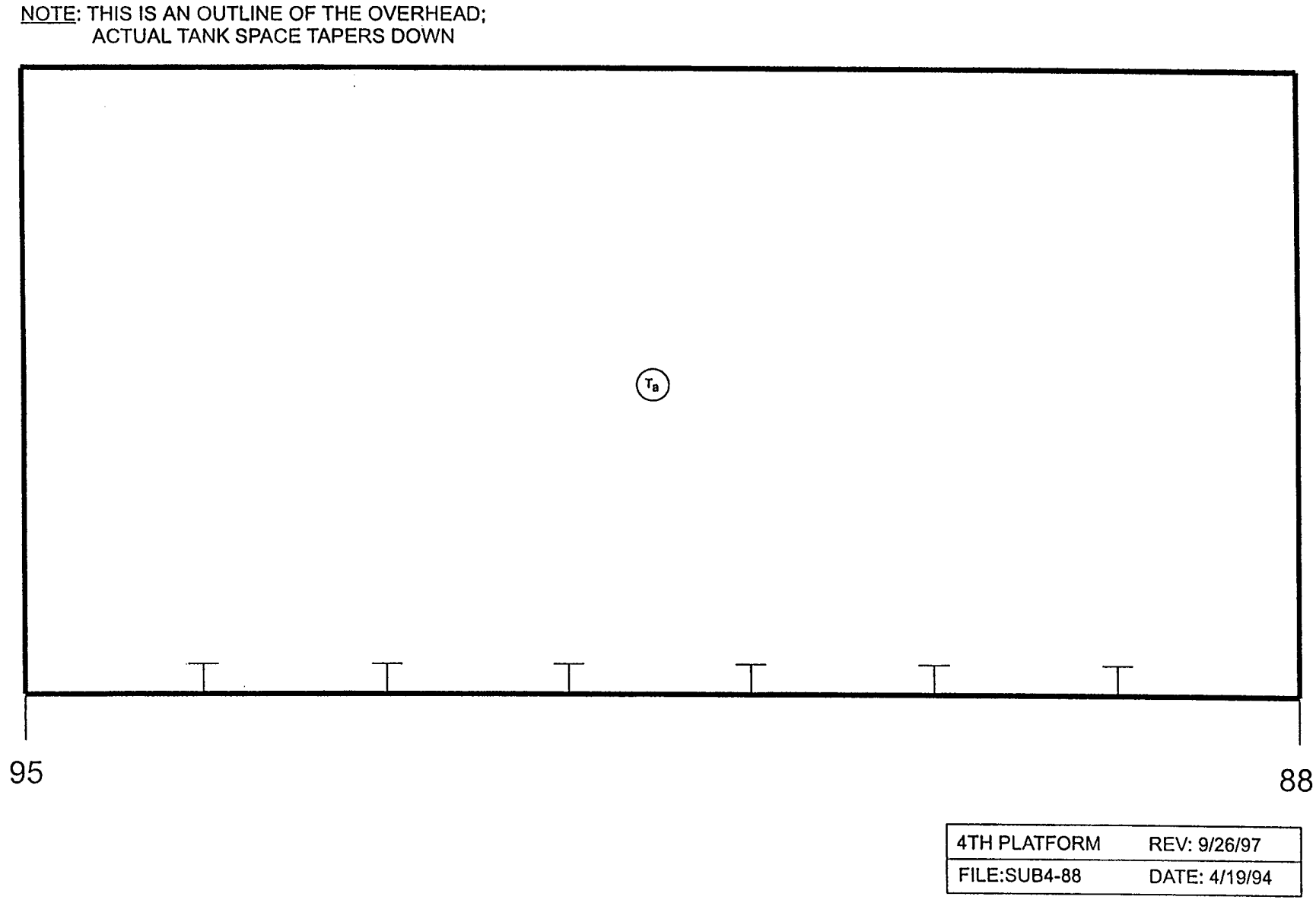


Fig. A18 – AMR Bilge instrumentation layout

Appendix B

Instrumentation Listing

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
OUTSIDE					
1	Anemometer	0-20 m/s	Flight Deck		As currently installed.
2	Wind Direction	0-360°(R)	Flight Deck		As currently installed.
3	Video Camera	N/A	Attached to flight deck at FR 100		Looking Forward (at H3 opening).
4	Video Camera	N/A	Attached to railing at FR 58		Looking Aft (at H1 & H2 openings).
5	Thermocouple	0-500° C			Ambient temperature.
BRIDGE ACCESS TRUNK (refer to Figure A-1)					
6	Thermocouple	0-500° C	1.5/0.0/0.0	N/A	0/0/0 coordinate for Bridge Access Trunk is aft, centerline, bottom.
7	Thermocouple	0-500° C	1.5/0.0/2.8	N/A	0/0/0 coordinate for Bridge Access Trunk is aft, centerline, bottom.
8	Bi-flow Probe	+/- 25 Pa	Lower Hatch - H1	WTS 01-82-2	Probe is mounted on a "removable" bracket located in the center of the hatch opening. Can be moved out of the way when the hatch is closed.
COMBAT SYSTEMS (1-74-2) (refer to Figure A-2)					
9	Video Camera	N/A	7.0/2.5/1.0	1-75-2	Coordinates represent approximate "lens" location.
10	Bi-flow Probe	+/- 25 Pa	5.5/1.3/0.0 (WTH - H5)	WTH 1-76-2	Probe is located in the approximate center of the opening. Mounted on "movable" bracket to facilitate personnel movement through this opening.
11	Thermocouple	0-500°C	5.5/1.3/0.0 (WTH - H5)	WTH 1-76-2	Located immediately adjacent to Bi-flow Probe (#10).
12	Thermocouple	0-500°C	4.5/2.0/3.5	1-77-2	Forward thermocouple string.
13	Thermocouple	0-500°C	4.5/2.0/3.0	1-77-2	Forward thermocouple string.

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
14	Thermocouple	0-500°C	4.5/2.0/2.5	1-77-2	Forward thermocouple string.
15	Thermocouple	0-500°C	4.5/2.0/2.0	1-77-2	Forward thermocouple string.
16	Thermocouple	0-500°C	4.5/2.0/1.5	1-77-2	Forward thermocouple string.
17	Thermocouple	0-500°C	4.5/2.0/1.0	1-77-2	Forward thermocouple string.
18	Thermocouple	0-500°C	4.5/2.0/0.5	1-77-2	Forward thermocouple string.
19	Thermocouple	0-500°C	4.5/2.0/0.05	1-77-2	Forward thermocouple string.
20	Diff. Pressure	+/-5000 Pa	4.5/2.0/2.5	1-77-2	Low side to ambient. Located with forward thermocouple string.
21	Diff. Pressure	+/- 125 Pa	4.5/2.0/1.0	1-77-2	Low side to ambient. Located with forward thermocouple string.
22	Optical Density Meter	0-100%	3.5/2.3/3.5	1-78-2	ODM bracket centered (vertically & horizontally) on coordinate (0.6 m off blkhd).
23	Optical Density Meter	0-100%	3.5/2.3/2.5	1-78-2	ODM bracket centered (vertically & horizontally) on coordinate (0.6 m off blkhd).
24	Optical Density Meter	0-100%	3.5/2.3/1.5	1-78-2	ODM bracket centered (vertically & horizontally) on coordinate (0.6 m off blkhd).
25	Thermocouple	0-500°C	2.0/1.5/3.5	1-80-2	Aft thermocouple string.
26	Thermocouple	0-500°C	2.0/1.5/3.0	1-80-2	Aft thermocouple string.
27	Thermocouple	0-500°C	2.0/1.5/2.5	1-80-2	Aft thermocouple string.
28	Thermocouple	0-500°C	2.0/1.5/2.0	1-80-2	Aft thermocouple string.
29	Thermocouple	0-500°C	2.0/1.5/1.5	1-80-2	Aft thermocouple string.

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
30	Thermocouple	0-500°C	2.0/1.5/1.0	1-80-2	Aft thermocouple string.
31	Thermocouple	0-500°C	2.0/1.5/0.5	1-80-2	Aft thermocouple string.
32	Thermocouple	0-500°C	2.0/1.5/0.05	1-80-2	Aft thermocouple string.
33	Bi-flow Probe	+/- 25 Pa	WTH - H2	WTS 1-82-2	Probe is located in the approximate center of the opening. Mounted on "movable" bracket to facilitate personnel movement through this opening.
34	Thermocouple	0-500°C	WTH - H2	WTS 1-82-2	Mounted immediately adjacent to Bi-flow Probe (#33).
35	Thermocouple (bulkhead)	0-500°C	0.0/1.0/1.5	1-81-2	Affix to aft bulkhead (bolt arrangement). ΔT measurement across bulkhead (refer to #33).
36	Flow Meter	0-300 gpm	–	1-75-2	Ultrasonic flowmeter.
37	Pressure	0-500 psig	–	1-79-2	Firemain pressure.
CONTROL ROOM (1-81-2) (refer to Figure A-3)					
38	Thermocouple (bulkhead)	0-500°C	8.55/1.0/1.5	1-83-2	Affix to forward bulkhead (immediately adjacent to #35).
39	Diff. Pressure	+/- 25 Pa	7.5/2.0/1.5	1-82-2	Located with forward thermocouple string. Low side to space 1-74-2 (on aft thermocouple string; 2.0/1.5/1.5).
40	Video Camera	N/A	8.0/2.3/0.1	1-81-2	Coordinate is approximate location of "lens."
41	Thermocouple	0-1000°C	7.5/2.0/2.5	1-82-2	Forward thermocouple string.
42	Thermocouple	0-1000°C	7.5/2.0/2.0	1-82-2	Forward thermocouple string.
43	Thermocouple	0-1000°C	7.5/2.0/1.5	1-82-2	Forward thermocouple string.

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
44	Thermocouple	0-1000°C	7.5/2.0/1.0	1-82-2	Forward thermocouple string.
45	Thermocouple	0-1000°C	7.5/2.0/0.5	1-82-2	Forward thermocouple string.
46	Thermocouple (deck)	0-1000°C	5.0/1.5/0.0	1-85-2	Affix thermocouple to deck. Provide ΔT through deck (refer to #188).
47	Thermocouple	0-1000°C	5.0/1.5/0.05	1-85-2	Immediately above #46.
48	Optical Density Meter	0-100%	4.3/2.4/2.5	1-85-2	Mounting bracket centered on coordinate.
49	Optical Density Meter	0-100%	4.3/2.4/1.5	1-85-2	Mounting bracket centered on coordinate.
50	Optical Density Meter	0-100%	4.3/2.4/0.5	1-85-2	Mounting bracket centered on coordinate.
51	Thermocouple	0-1000°C	2.0/1.5/2.5	1-86-2	Aft thermocouple string.
52	Thermocouple	0-1000°C	2.0/1.5/2.0	1-86-2	Aft thermocouple string.
53	Thermocouple	0-1000°C	2.0/1.5/1.5	1-86-2	Aft thermocouple string.
54	Thermocouple	0-1000°C	2.0/1.5/1.0	1-86-2	Aft thermocouple string.
55	Thermocouple	0-1000°C	2.0/1.5/0.5	1-86-2	Aft thermocouple string.
56	Diff. Pressure	+/- 5000 Pa	7.5/2.0/2.5	1-86-2	Low side to ambient. Located with forward thermocouple string.
57	Diff. Pressure	+/- 125 Pa	7.5/2.0/1.0	1-86-2	Low side to ambient. Located with forward thermocouple string.
58	O_2 Gas Sample	0-25%	2.0/1.5/2.5	1-82-2	Upper Layer sample. Located with forward thermocouple string (also serves Torpedo Room).
59	O_2 Gas Sample	0-25%	7.5/1.5/1.0	1-82-2	Lower Layer sample. Located with forward thermocouple string (also serves Torpedo Room).

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
60	CO Gas Sample	0-2.5%	7.5/1.5/2.5	1-82-2	Upper Layer sample. Located with forward thermocouple string (also serves Torpedo Room).
61	CO Gas Sample	0-2.5%	7.5/1.5/1.0	1-82-2	Lower Layer sample. Located with forward thermocouple string (also serves Torpedo Room).
62	CO_2 Gas Sample	0-20%	7.5/1.5/2.5	1-82-2	Upper Layer sample. Located with forward thermocouple string (also serves Torpedo Room).
63	CO_2 Gas Sample	0-5%	7.5/1.5/1.0	1-82-2	Lower Layer sample. Located with forward thermocouple string (also serves Torpedo Room).
64	Bi-flow Probe	+/- 25 Pa	0.5/1.8/0.0 (WTH - H4)	WTH 1-87-2	Probe is located in the approximate center of the opening. Mounted on "movable" bracket to facilitate personnel movement through this opening.
65	Thermocouple	0-1000°C	0.5/1.8/0.0 (WTH - H4)	WTH 1-87-2	Mounted immediately adjacent to the Bi-flow Probe (#64).
66	Thermocouple (bulkhead)	0-500°C	0.0/1.0/1.5	1-88-2	Affixed to aft bulkhead. ΔT across bulkhead (refer to #85).
67	Thermocouple (deck)	0-1000°C	2.0/2.0/0.0	1-86-2	Affixed to deck. ΔT across deck (refer to #226).
68	Thermocouple	0-1000°C	2.0/2.0/0.05	1-86-2	Installed immediately above #67.
69	Thermocouple (deck)	0-1000°C	2.0/1.0/0.0	1-86-4	Affixed to deck. ΔT across deck (refer to #227).
70	Thermocouple	0-1000°C	2.0/1.0/0.05	1-86-4	Installed immediately above #69.
71	Thermocouple (deck)	0-1000°C	2.0/-0.05/0.0	1-86-6	Affixed to deck. ΔT across deck (refer to #229). On weather deck.
72	Thermocouple	0-1000°C	2.0/-0.05/0.05	1-86-6	Installed immediately above #71. Needs to be protected.
73	Thermocouple (deck)	0-1000°C	6.5/2.0/0.0	1-82-2	Affixed to deck. ΔT across deck (refer to #223).

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
74	Thermocouple	0-1000°C	6.5/2.0/0.05	1-82-2	Installed immediately above #73.
75	Thermocouple (deck)	0-1000°C	6.5/1.0/0.0	1-82-4	Affixed to deck. ΔT across deck (refer to #224).
76	Thermocouple	0-1000°C	6.5/1.0/0.05	1-82-4	Installed immediately above #75.
77	Thermocouple (deck)	0-1000°C	6.5/-0.05/0.0	1-82-6	Affixed to deck. ΔT across deck (refer to #225). On weather deck.
78	Thermocouple	0-1000°C	6.5/-0.05/0.05	1-82-6	Installed immediately above #77.
79	Thermocouple	0-1000°C	4.2/1.5/2.5	1-83-2	Additional "modeling data" thermocouple string.
80	Thermocouple	0-1000°C	4.2/1.5/2.0	1-83-2	Additional "modeling data" thermocouple string.
81	Thermocouple	0-1000°C	4.2/1.5/1.5	1-83-2	Additional "modeling data" thermocouple string.
82	Thermocouple	0-1000°C	4.2/1.5/1.0	1-83-2	Additional "modeling data" thermocouple string.
83	Thermocouple	0-1000°C	4.2/1.5/0.5	1-83-2	Additional "modeling data" thermocouple string.
84	Thermocouple	0-1000°C	4.2/1.5/0.05	1-83-2	Additional "modeling data" thermocouple string.
FAN ROOM (1-88-2) (refer to Figures A-4, A-5, & A-6)					
85	Thermocouple (bulkhead)	0-500°C	8.55/1.0/1.5	1-88-2	Affixed to forward bulkhead. ΔT with respect to #66.
86	Diff. Pressure	+/- 125 Pa	5.0/0.7/2.5	1-92-2	Low side to 1-83-2 (at 2.0/1.0/1.5). Located with thermocouples.
87	Thermocouple	0-500°C	5.0/0.7/3.5	1-91-2	Upper ambient temperature.
88	Thermocouple	0-500°C	5.0/0.7/1.0	1-91-2	Lower ambient temperature.
89	Bi-flow Probe	+/- 250 Pa	Supply Vent. Outlet 1-83-2		Probe centered in the ducting and oriented parallel to air flow.

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Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
90	Thermocouple	0-1000°C	1-83-2		Installed immediately adjacent to #89.
91	Bi-flow Probe	+/- 250 Pa	Exhaust Vent. Inlet 1-88-2		Probe centered in the ducting and oriented parallel to air flow.
92	Thermocouple	0-1000°C	1-88-2		Installed immediately adjacent to #91.
93	Bi-flow Probe	+/- 100 Pa	NAV Equip. L.P. Blower Exh. Duct 1-96-2		Probe in the outlet ducting of the L.P. blower, centered in the ducting and oriented parallel to flow.
94	Thermocouple	0-1000°C	NAV Equip. L.P. Blower Exh. Duct		Installed immediately adjacent to #93.
95	Bi-flow Probe	+/- 250 Pa	Induction Sys. Inlet 1-96-2		Probe in the induction system inlet ducting, centered in the ducting and oriented parallel to flow.
96	Thermocouple	0-100°C	Induction System Inlet 1-96-2		Installed immediately adjacent to #95.
97	Bi-flow Probe	+/- 250 Pa	AMR L.P. Blower Exh. Duct 3-90-2		Probe in the outlet ducting of the L.P. blower, centered in the ducting and oriented parallel to flow.
98	Thermocouple	0-1000°C	AMR L.P. Blower Exh. Duct 3-90-2		Installed immediately adjacent to #97.
99	Optical Density Meter	0-100%	3.6/2.4/1.5	1-92-2	Mounting bracket centered on coordinate.
100	Bi-flow Probe	0-25 Pa	7.0/2.5/1.0	1-90-2	Common AMR Framebay in Fan Room.
101	Thermocouple	0-1000°C	7.0/2.5/1.0	1-90-2	Bi-flow thermocouple located at probe (#100).
102	Bi-flow Probe	+/-125 Pa	7.0/2.5/3.0	1-94-2	AMR L.P. blower exhaust ducting.
103	Thermocouple	0-1000°C	7.0/2.5/3.0	1-94-2	Installed immediately adjacent to bi-flow probe (refer to #102).

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Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
CPO LIVING (2-68-2) (refer to Figure A-7)					
104	Thermocouple	0-500°C	0.0/2.0/2.5	2-67-2	Measured from within (current) "DC Locker."
105	Thermocouple	0-500°C	0.0/2.0/1.0	2-67-2	Measured from within (current) "DC Locker."
106	Thermocouple	0-500°C	2.0/1.5/2.5	2-72-2	Thermocouple string.
107	Thermocouple	0-500°C	2.0/1.5/2.0	2-72-2	Thermocouple string.
108	Thermocouple	0-500°C	2.0/1.5/1.5	2-72-2	Thermocouple string.
109	Thermocouple	0-500°C	2.0/1.5/1.0	2-72-2	Thermocouple string.
110	Thermocouple	0-500°C	2.0/1.5/0.5	2-72-2	Thermocouple string.
111	Optical Density Meter	0-100%	2.5/0.6/2.5	2-71-2	Mounting bracket centered on the coordinate.
112	Optical Density Meter	0-100%	2.5/0.6/1.5	2-71-2	Mounting bracket centered on the coordinate.
113	Optical Density Meter	0-100%	2.5/0.6/0.5	2-71-2	Mounting bracket centered on the coordinate.
114	Thermocouple (bulkhead)	0-500°C	0.0/2.0/0.97	2-71-2	Affixed to aft bulkhead. ΔT across bulkhead (refer to #117).
CREW LIVING (2-74-2) (refer to Figure A-8)					
115	Diff. Pressure	+/- 25 Pa	7.0/3.0/1.5	2-75-2	Low side to 2-69-2 (at 2.0/1.5/1.5). Located with forward thermocouple string.
116	Diff. Pressure	+/- 25 Pa	7.0/1.5/2.5	2-83-2	Low side to 1-83-2 (at 7.0/1.5/1.0). Located with forward thermocouple string.
117	Thermocouple (bulkhead)	0-500°C	8.55/2.0/0.95	2-74-2	Affixed to forward bulkhead, adjacent to #114.

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Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
118	Video Camera	N/A	7.3/3.5/0.1	2-76-2	Coordinate is approximate "lens" location.
119	Thermocouple	0-1000°C	7.0/3.0/2.5	2-75-2	Forward thermocouple string.
120	Thermocouple	0-1000°C	7.0/3.0/2.0	2-75-2	Forward thermocouple string.
121	Thermocouple	0-1000°C	7.0/3.0/1.5	2-75-2	Forward thermocouple string.
122	Thermocouple	0-1000°C	7.0/3.0/1.0	2-75-2	Forward thermocouple string.
123	Thermocouple	0-1000°C	7.0/3.0/0.5	2-75-2	Forward thermocouple string.
124	Thermocouple	0-1000°C	7.0/3.0/0.05	2-75-2	Forward thermocouple string.
125	Thermocouple (deck)	0-500°C	4.5/2.0/0.0	2-77-2	Affixed to deck. ΔT through deck (refer to #274).
126	Optical Density Meter	0-100%	4.0/3.6/2.5	2-77-2	Mounting bracket centered on coordinate.
127	Optical Density Meter	0-100%	4.0/3.6/1.5	2-77-2	Mounting bracket centered on coordinate.
128	Optical Density Meter	0-100%	4.0/3.6/0.5	2-77-2	Mounting bracket centered on coordinate.
129	Thermocouple	0-1000°C	2.3/2.2/2.5	2-79-2	Aft thermocouple string.
130	Thermocouple	0-1000°C	2.3/2.2/2.0	2-79-2	Aft thermocouple string.
131	thermocouple	0-1000°C	2.3/2.2/1.5	2-79-2	Aft thermocouple string.
132	Thermocouple	0-1000°C	2.3/2.2/1.0	2-79-2	Aft thermocouple string.
133	Thermocouple	0-1000°C	2.3/2.2/0.5	2-79-2	Aft thermocouple string.
134	Thermocouple	0-1000°C	2.3/2.2/0.05	2-79-2	Aft thermocouple string.

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Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
135	Diff. Pressure	+/- 25 Pa	2.3/2.2/0.5	2-78-2	Low side to 2-72-2 (at 7.0/1.5/1.0). Located with forward thermocouple string.
136	Diff. Pressure	+/- 125 Pa	2.3/2.2/2.5	2-78-2	Low side to ambient. Located with forward thermocouple string.
137	Diff. Pressure	+/- 125 Pa	2.3/2.2/1.0	2-78-2	Low side to ambient. Located with forward thermocouple string.
138	Thermocouple	0-500°C	7.0/1.0/2.5	2-75-2	Additional "modeling data" thermocouple string.
139	Thermocouple	0-500°C	7.0/1.0/2.0	2-75-2	Additional "modeling data" thermocouple string.
140	Thermocouple	0-500°C	7.0/1.0/1.5	2-75-2	Additional "modeling data" thermocouple string.
141	Thermocouple	0-500°C	7.0/1.0/1.0	2-75-2	Additional "modeling data" thermocouple string.
142	Thermocouple	0-500°C	7.0/1.0/0.5	2-75-2	Additional "modeling data" thermocouple string.
143	Thermocouple	0-500°C	7.0/1.0/0.05	2-75-2	Additional "modeling data" thermocouple string.
144	Thermocouple (bulkhead)	0-500°C	0.0/0.5/2.3	2-81-2	Affixed to aft bulkhead. ΔT across bulkhead (refer to #162).
145	Thermocouple	0-500°C	0.05/0.5/2.3	2-81-2	Immediately adjacent to #144.
146	Thermocouple (bulkhead)	0-500°C	0.0/1.5/2.3	2-81-4	Affixed to aft bulkhead. ΔT across bulkhead (refer to #164).
147	Thermocouple	0-500°C	0.05/1.5/2.3	2-81-4	Immediately adjacent to #146.
148	Thermocouple (bulkhead)	0-500°C	0.0/1.5/1.5	2-81-4	Affixed to aft bulkhead. ΔT across bulkhead (refer to #166).
149	Thermocouple	0-500°C	0.05/1.5/1.5	2-81-4	Immediately adjacent to #148.
150	Thermocouple (bulkhead)	0-500°C	0.0/1.5/0.5	2-81-4	Affixed to aft bulkhead. ΔT across bulkhead (refer to #168).
151	Thermocouple	0-500°C	0.05/1.5/0.5	2-81-4	Immediately adjacent to #150.

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Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
152	Thermocouple (bulkhead)	0-500°C	0.0/2.5/2.3	2-81-6	Affixed to aft bulkhead. ΔT across bulkhead (refer to #170).
153	Thermocouple	0-500°C	0.05/2.5/2.3	2-81-6	Immediately adjacent to #152.
154	Thermocouple (bulkhead)	0-500°C	0.0/2.5/1.5	2-81-6	Affixed to aft bulkhead. ΔT across bulkhead (refer to #172).
155	Thermocouple	0-500°C	0.05/2.5/1.5	2-81-6	Immediately adjacent to #154.
156	Thermocouple (bulkhead)	0-500°C	0.0/2.5/0.5	2-81-6	Affixed to aft bulkhead. ΔT across bulkhead (refer to #174).
157	Thermocouple	0-500°C	0.05/2.5/0.5	2-81-6	Immediately adjacent to #156.
158	Bi-flow Probe	+/- 25 Pa	7.0/3.6/1.0	2-76-4	Installed immediately adjacent to Bi-flow probe, #203.
159	Thermocouple	0-1000°C	7.0/3.6/1.0	2-76-4	Located above fuel cradle, just below the overhead (plume temp).
160	Bi-flow Probe	+/- 25 Pa	7.0/0.3/1.0	2-76-2	Installed immediately adjacent to Bi-flow probe, #203.
161	Thermocouple	0-1000°C	7.0/0.3/1.0	2-76-2	Located above fuel cradle, just below the overhead (plume temp).
WARDROOM (2-81-2) (refer to Figures A-9 & A-10)					
162	Thermocouple (bulkhead)	0-1000°C	8.55/1.63/2.3	2-81-2	Affixed to forward bulkhead, opposite #144.
163	Thermocouple	0-1000°C	8.50/1.63/2.3	2-81-2	Immediately adjacent #162.
164	Thermocouple (bulkhead)	0-1000°C	8.55/2.63/2.3	2-81-4	Affixed to forward bulkhead, opposite #146.
165	Thermocouple	0-1000°C	8.50/2.63/2.3	2-81-4	Immediately adjacent #164.
166	Thermocouple (bulkhead)	0-1000°C	8.55/2.63/1.5	2-81-4	Affixed to forward bulkhead, opposite #148.
167	Thermocouple	0-1000°C	1740/2.63/1.5	2-81-4	Immediately adjacent #166.

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Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
168	Thermocouple (bulkhead)	0-1000°C	8.55/2.63/0.5	2-81-4	Affixed to forward bulkhead, opposite #150.
169	Thermocouple	0-1000°C	8.50/2.63/0.5	2-81-4	Immediately adjacent #168.
170	Thermocouple (bulkhead)	0-1000°C	8.55/3.63/2.3	2-81-6	Affixed to forward bulkhead, opposite #152.
171	Thermocouple	0-1000°C	8.50/3.63/2.3	2-81-6	Immediately adjacent #170.
172	Thermocouple (bulkhead)	0-1000°C	8.55/3.63/1.5	2-81-6	Affixed to forward bulkhead, opposite #154.
173	Thermocouple	0-1000°C	8.50/3.63/1.5	2-81-6	Immediately adjacent #172.
174	Thermocouple (bulkhead)	0-1000°C	8.55/3.63/0.5	2-81-6	Affixed to forward bulkhead, opposite #156.
175	Thermocouple	0-1000°C	8.50/3.63/0.5	2-81-6	Immediately adjacent #174.
176	Video Camera	N/A	8.1/3.8/0.1	2-82-2	Coordinate is the approximate "lens" location (looking down Wardroom passageway).
177	Video Camera	N/A	8.1/1.0/0.1	2-82-4	Coordinate is the approximate "lens" location (looking into Wardroom).
178	Thermocouple	0-1000°C	6.5/2.0/2.5	2-82-0	Forward thermocouple string.
179	Thermocouple	0-1000°C	6.5/2.0/2.0	2-82-0	Forward thermocouple string.
180	Thermocouple	0-1000°C	6.5/2.0/1.5	2-82-0	Forward thermocouple string.
181	thermocouple	0-1000°C	6.5/2.0/1.0	2-82-0	Forward thermocouple string.
182	Thermocouple	0-1000°C	6.5/2.0/0.5	2-82-0	Forward thermocouple string.
183	Thermocouple	0-1000°C	6.5/2.0/0.05	2-82-0	Forward thermocouple string.

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Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
184	Bi-flow Probe	+/- 25 Pa	WTH - H7 (5.5/3.0/0.0)	WTH 2-83-2	Probe is located in the approximate center of the opening. Mounted on "movable" bracket to facilitate personnel movement through this opening.
185	Thermocouple	0-1000°C	WTH - H7 (5.5/3.0/0.0)	WTH 2-83-2	Mounted immediately adjacent to Bi-flow Probe, #184.
186	Diff. Pressure	+/- 25 Pa	6.5/2.0/2.5	2-82-0	Low side to ambient. Located with forward thermocouple string.
187	Diff. Pressure	+/- 25 Pa	6.5/2.0/1.0	2-82-0	Low side to ambient. Located with forward thermocouple string.
188	Thermocouple (deck)	0-1000°C	5.0/2.5/2.59	2-84-2	Affixed to overhead, opposite #46.
189	Thermocouple	0-1000°C	5.0/2.5/2.54	2-84-2	Immediately below #188.
190	Thermocouple (deck)	0-1000°C	5.0/1.5/0.0	2-84-2	Affixed to deck. Provides ΔT through deck (refer to #315).
191	Thermocouple	0-1000°C	2.0/1.0/2.5	2-86-2	Aft thermocouple string.
192	Thermocouple	0-1000°C	2.0/1.0/2.0	2-86-2	Aft thermocouple string.
193	Thermocouple	0-1000°C	2.0/1.0/1.5	2-86-2	Aft thermocouple string.
194	Thermocouple	0-1000°C	2.0/1.0/1.0	2-86-2	Aft thermocouple string.
195	Thermocouple	0-1000°C	2.0/1.0/0.5	2-86-2	Aft thermocouple string.
196	Thermocouple	0-1000°C	2.0/1.0/0.05	2-86-2	Aft thermocouple string.
197	O_2 Gas Sample	0-25%	2.0/1.0/2.5	2-86-2	Upper layer sample. Located with forward thermocouple string (also serves Laundry).

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Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
198	O_2 Gas Sample	0-25%	2.0/1.0/1.0	2-86-2	Lower layer sample. Located with forward thermocouple string (also serves Laundry).
199	CO Gas Sample	0-10%	2.0/1.0/2.5	2-86-2	Upper layer sample. Located with forward thermocouple string (also serves Laundry).
200	CO Gas Sample	0-10%	2.0/1.0/1.0	2-86-2	Lower layer sample. Located with forward thermocouple string (also serves Laundry).
201	CO_2 Gas Sample	0-20%	2.0/1.0/2.5	2-86-2	Upper layer sample. Located with forward thermocouple string (also serves Laundry).
202	CO_2 Gas Sample	0-20%	2.0/1.0/1.0	2-86-2	Lower layer sample. Located with forward thermocouple string (also serves Laundry).
203	Thermocouple (bulkhead)	0-1000°	0.0/2.0/0.92	2-88-2	Affixed to aft bulkhead.
204	Bi-flow Probe	+/- 125 Pa	Wardroom Exhaust Vent. Duct 2-87-2		Probe centered within the duct, parallel to flow, and as close as practical to the "sleeve" penetrating the ship's hull.
205	Thermocouple	0-1000°C	Wardroom Exhaust Vent. Duct 2-87-2		Installed immediately adjacent to Bi-flow Probe, #204.
206	Thermocouple	0-1000°C	6.5/3.0/2.5	2-83-6	Additional "modeling data" thermocouple string.
207	Thermocouple	0-1000°C	6.5/3.0/2.0	2-83-6	Additional "modeling data" thermocouple string.
208	Thermocouple	0-1000°C	6.5/3.0/1.5	2-83-6	Additional "modeling data" thermocouple string.
209	Thermocouple	0-1000°C	6.5/3.0/1.0	2-83-6	Additional "modeling data" thermocouple string.
210	Thermocouple	0-1000°C	6.5/3.0/0.5	2-83-6	Additional "modeling data" thermocouple string.

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
211	Thermocouple	0-1000°C	6.5/3.0/0.05	2-83-6	Additional "modeling data" thermocouple string.
212	Thermocouple	0-1000°C	6.5/0.8/2.5	2-83-2	Additional "modeling data" thermocouple string.
213	Thermocouple	0-1000°C	6.5/0.8/2.0	2-83-2	Additional "modeling data" thermocouple string.
214	Thermocouple	0-1000°C	6.5/0.8/1.5	2-83-2	Additional "modeling data" thermocouple string.
215	Thermocouple	0-1000°C	6.5/0.8/1.0	2-83-2	Additional "modeling data" thermocouple string.
216	Thermocouple	0-1000°C	6.5/0.8/0.5	2-83-2	Additional "modeling data" thermocouple string.
217	Thermocouple	0-1000°C	6.5/0.8/0.05	2-83-2	Additional "modeling data" thermocouple string.
218	Thermocouple	0-1000°C	2.0/3.0/2.5	2-86-4	Additional "modeling data" thermocouple string.
219	Thermocouple	0-1000°C	2.0/3.0/2.0	2-86-4	Additional "modeling data" thermocouple string.
220	Thermocouple	0-1000°C	2.0/3.0/1.5	2-86-4	Additional "modeling data" thermocouple string.
221	Thermocouple	0-1000°C	2.0/3.0/1.0	2-86-4	Additional "modeling data" thermocouple string.
222	Thermocouple	0-1000°C	2.0/3.0/0.5	2-86-4	Additional "modeling data" thermocouple string.
223	Thermocouple	0-1000°C	2.0/3.0/0.05	2-86-4	Additional "modeling data" thermocouple string.
224	Thermocouple (deck)	0-1000°C	6.5/3.0/2.59	2-83-6	Affixed to overhead, opposite #73.
225	Thermocouple (deck)	0-1000°C	6.5/2.0/2.59	2-83-4	Affixed to overhead, opposite #75.
226	Thermocouple (deck)	0-1000°C	6.5/0.8/2.59	2-83-2	Affixed to overhead, opposite #77.
227	Thermocouple (deck)	0-1000°C	2.0/3.0/2.59	2-86-6	Affixed to overhead, opposite #67.

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
228	Thermocouple (deck)	0-1000°C	2.0/2.0/2.59	2-86-4	Affixed to overhead, opposite #69.
229	Thermocouple	0-1000°C	2.0/2.0/2.54	2-86-2	Immediately below #228.
230	Thermocouple (deck)	0-1000°C	2.0/1.0/2.59	2-86-2	Affixed to overhead, opposite #71.
231	Optical Density Meter	0-100%	3.5/0.6/2.5	2-84-2	Mounting bracket centered on coordinate.
232	Optical Density Meter	0-100%	3.5/0.6/1.5	2-84-2	Mounting bracket centered on coordinate.
233	Optical Density Meter	0-100%	3.5/0.6/0.5	2-84-2	Mounting bracket centered on coordinate.
234	Diff. Pressure	+/-25 Pa	6.5/2.0/2.48	2-82-0	Low side to Control Room at forward thermocouple string at 1.0 height.
235	Bi-flow Probe	+/- 25 Pa	7.0/3.6/1.0	2-84-4	Probe centered in frame bay and oriented parallel to flow.
236	Thermocouple	0-1000°C	7.0/3.6/1.0	2-84-4	Installed immediately adjacent to Bi-flow probe, #235.
237	Bi-flow Probe	+/- 25 Pa	7.0/0.3/1.0	2-84-2	Probe centered in frame bay and oriented parallel to flow.
238	Thermocouple	0-1000°C	7.0/0.3/1.0	2-84-2	Installed immediately adjacent to Bi-flow probe, #237.
CPO/CREW MESS ROOM (2-88-4) (refer to Figure A-11)					
239	Thermocouple (bulkhead)	0-1000°C	8.51/2.0/0.92	2-88-2	Affixed to forward bulkhead, opposite #203.
240	Thermocouple	0-1000°C	7.0/2.0/2.5	2-89-2	Forward thermocouple string.
241	Thermocouple	0-1000°C	7.0/2.0/2.0	2-89-2	Forward thermocouple string.
242	Thermocouple	0-1000°C	7.0/2.0/1.5	2-89-2	Forward thermocouple string.
243	Thermocouple	0-1000°C	7.0/2.0/1.0	2-89-2	Forward thermocouple string.

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
244	Thermocouple	0-1000°C	7.0/2.0/0.5	2-89-2	Forward thermocouple string.
245	Diff. Pressure	+/- 25 Pa	7.0/2.0/2.5	2-89-2	Low side to 2-83-2 (at forward thermocouple string, 2.0/1.0/2.5). Located with forward thermocouple string.
246	Thermocouple (deck)	0-500°C	7.0/2.0/0.0	2-89-2	Affixed to deck. ΔT through deck (refer to #346).
247	Thermocouple	0-500°C	1.5/1.5/2.5	2-93-2	Aft thermocouple string.
248	Thermocouple	0-500°C	1.5/1.5/2.0	2-93-2	Aft thermocouple string.
249	Thermocouple	0-500°C	1.5/1.5.1.5	2-93-2	Aft thermocouple string.
250	Thermocouple	0-500°C	1.5/1.5/1.0	2-93-2	Aft thermocouple string.
251	Thermocouple	0-500°C	1.5/1.5/0.5	2-93-2	Aft thermocouple string.
252	Video Camera	N/A	0.0/1.0/0.3	2-95-2	Coordinate is approximate location of "lens."
253	Optical Density Meter	0-100%	6.0/1.0/2.5	2-95-2	Mounting bracket centered on coordinate.
254	Optical Density Meter	0-100%	6.0/1.0/1.5	2-95-2	Mounting bracket centered on coordinate.
255	IR Camera	N/A	Mobile	Mobile	Mobile Argus camera with Safety Team member
FORWARD ESCAPE TRUNK (@ FR. 95)					
256	Bi-flow Probe	+/- 25 Pa	WTS - H3	WTS 1-96-1	Probe is located in the approximate center of the opening. Mounted on "movable" bracket to facilitate personnel movement through this opening.
257	Thermocouple	0-500°C	WTS - H3	WTS 1-96-1	Located immediately adjacent to Bi-flow Probe, #256.
258	Bi-flow Probe	0-25 Pa	7.0/2.5/2.5	2-90-2	FR90 bi-directional probe.

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
259	Thermocouple	0-1000°C	7.0/2.5/2.5	2-90-2	Located immediately adjacent to Bi-flow Probe #258.
STOREROOM (3-67-2) (refer to Figure A-12)					
260	Thermocouple	0-500°C	2.0/1.5/2.5	3-72-2	Thermocouple string.
261	Thermocouple	0-500°C	2.0/1.5/2.0	3-72-2	Thermocouple string.
262	Thermocouple	0-500°C	2.0/1.5/1.5	3-72-2	Thermocouple string.
263	Thermocouple	0-500°C	2.0/1.5/1.0	3-72-2	Thermocouple string.
264	Thermocouple	0-500°C	2.0/1.5/0.5	3-72-2	Thermocouple string.
265	Thermocouple (bulkhead)	0-500°C	0.0/1.0/1.5	3-74-2	Affixed to aft bulkhead. ΔT through bulkhead (refer to #266).
TORPEDO ROOM (3-74-2) (refer to Figure A-13)					
266	Thermocouple (bulkhead)	0-500°C	8.5/1.0/1.5	3-74-2	Affixed to forward bulkhead, immediately opposite #265.
267	Thermocouple	0-1000°C	7.2/1.5/2.5	3-75-2	Forward thermocouple string.
268	Thermocouple	0-1000°C	7.2/1.5/2.0	3-75-2	Forward thermocouple string.
269	Thermocouple	0-1000°C	7.2/1.5/1.5	3-75-2	Forward thermocouple string.
270	Thermocouple	0-1000°C	7.2/1.5/1.0	3-75-2	Forward thermocouple string.
271	Thermocouple	0-1000°C	7.2/1.5/0.5	3-75-2	Forward thermocouple string.
272	Thermocouple	0-1000°C	7.2/1.5/0.05	3-75-2	Forward thermocouple string.
273	Diff. Pressure	+/- 25 Pa	7.2/1.5/2.5	3-76-2	Low side to 3-72-2 (at 2.0/1.5/2.4). Located with forward thermocouple string.

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
274	Diff. Pressure	+/- 25 Pa	7.2/1.5/1.5	3-76-2	Low side to 3-79-2 (at 2.0/1.5/1.5). Located with forward thermocouple string.
275	Thermocouple (deck)	0-500°C	5.0/2.2/0.0	3-77-2	Affixed to deck. ΔT through the deck (refer to #371).
276	Thermocouple (deck)	0-500°C	4.5/2.0/2.58	3-77-2	Affixed to overhead, opposite #125.
277	Optical Density Meter	0-100%	4.0/3.6/2.5	3-78-2	Mounting bracket centered on coordinate.
278	Optical Density Meter	0-100%	4.0/3.6/1.5	3-78-2	Mounting bracket centered on coordinate.
279	Optical Density Meter	0-100%	4.0/3.6/0.5	3-78-2	Mounting bracket centered on coordinate.
280	Thermocouple	0-1000°C	2.3/2.3/2.5	3-78-2	Aft thermocouple string (use existing stanchions to mount).
281	Thermocouple	0-1000°C	2.3/2.3/2.0	3-78-2	Aft thermocouple string.
282	Thermocouple	0-1000°C	2.3/2.3/1.5	3-78-2	Aft thermocouple string.
283	Thermocouple	0-1000°C	2.3/2.3/1.0	3-78-2	Aft thermocouple string.
284	Thermocouple	0-1000°C	2.3/2.3/0.5	3-78-2	Aft thermocouple string.
285	Thermocouple	0-1000°C	2.3/2.3/0.05	3-78-2	Aft thermocouple string.
286	O_2 Gas Sample	0-25%	2.3/2.3/2.5	3-78-2	Upper layer sample. Located with forward thermocouple string (also serves Control Room).
287	O_2 Gas Sample	0-25%	2.3/2.3/1.0	3-78-2	Lower layer sample. Located with forward thermocouple string (also serves Control Room).
288	CO Gas Sample	0-10%	2.3/2.3/2.5	3-78-2	Upper Layer sample. Located with forward thermocouple string (also serves Control Room).

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
289	CO Gas Sample	0-10%	2.3/2.3/1.0	3-78-2	Lower layer sample. Located with forward thermocouple string (also serves Control Room).
290	CO_2 Gas Sample	0-20%	2.3/2.3/2.5	3-78-2	Upper layer sample. Located with forward thermocouple string (also serves Control Room).
291	CO_2 Gas Sample	0-20%	2.3/2.3/1.0	3-78-2	Lower layer sample. Located with forward thermocouple string (also serves Control Room).
292	Video Camera	N/A	7.5/0.5/1.0	3-74-2	Coordinate is approximate location of "lens."
293	Thermocouple (bulkhead)	0-1000°C	0.0/0.5/1.5	3-81-2	Affixed to aft bulkhead. ΔT through the bulkhead (refer to #297).
294	Thermocouple	0-1000°C	6.3/3.4/2.58	3-75-2	Installed in H8 opening; immediately adjacent to #346.
295	Bi-Flow	+/-25 Pa	6.3/3.4/2.58	3-75-2	Centered opening of H8.
296	Diff. Pressure	+/-25 Pa	7.2/1.5/2.52	3-75-0	Low side to Crew Living (2-74-2). Located at forward thermocouple string at 1.0 m height.
LAUNDRY (3-81-2) (refer to Figure A-14)					
297	Thermocouple (bulkhead)	0-1000°C	8.53/1.7/1.5	3-81-2	Affixed to forward bulkhead, opposite #293.
298	IR Camera	N/A	0.3/1.0/0.5	3-88-2	Coordinate is approximate location of "lens."
299	Diff. Pressure	+/- 125 Pa	6.5/3.0/1.5	3-82-2	Low side to 4-81-2.
300	Thermocouple	0-1000°C	7.0/1.5/2.5	3-82-2	Forward thermocouple string.
301	Thermocouple	0-1000°C	7.0/1.5/2.0	3-82-2	Forward thermocouple string.
302	Thermocouple	0-1000°C	7.0/1.5/1.5	3-82-2	Forward thermocouple string.

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
303	Thermocouple	0-1000°C	7.0/1.5/1.0	3-82-2	Forward thermocouple string.
304	Thermocouple	0-1000°C	7.0/1.5/0.5	3-82-2	Forward thermocouple string.
305	Thermocouple	0-1000°C	7.0/1.5/0.05	3-82-2	Forward thermocouple string.
306	Diff. Pressure	+/- 5000 Pa	7.0/1.5/2.5	3-82-2	Low side to ambient. Located with forward thermocouple string.
307	Diff. Pressure	+/- 5000 Pa	7.0/1.5/1.0	3-82-2	Low side to ambient. Located with forward thermocouple string.
308	Optical Density Meter	0-100%	2.0/3.3/2.5	3-85-2	Mounting bracket centered on coordinate.
309	Optical Density Meter	0-100%	2.0/3.3/1.5	3-85-2	Mounting bracket centered on coordinate.
310	Optical Density Meter	0-100%	2.0/3.3/0.5	3-85-2	Mounting bracket centered on coordinate.
311	O_2 Gas Sample	0-25%	7.0/1.5/2.5	3-82-0	Upper layer sample. Located with forward thermocouple string (also serves Wardroom).
312	O_2 Gas Sample	0-25%	7.0/1.5/1.0	3-82-0	Lower layer sample. Located with forward thermocouple string (also serves Wardroom).
313	CO Gas Sample	0-10%	7.0/1.5/2.5	3-82-2	Upper layer sample. Located with forward thermocouple string (also serves Wardroom).
314	CO Gas Sample	0-10%	7.0/1.5/1.0	3-82-2	Lower layer sample. Located with forward thermocouple string (also serves Wardroom).
315	CO_2 Gas Sample	0-20%	7.0/1.5/2.5	3-82-2	Upper layer sample. Located with forward thermocouple string (also serves Wardroom).
316	CO_2 Gas Sample	0-20%	7.0/1.5/1.0	3-82-2	Lower layer sample. Located with forward thermocouple string (also serves Wardroom).

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
317	Thermocouple (deck)	0-1000°C	5.0/1.5/2.56	3-84-2	Affixed to the overhead, opposite #190.
318	Thermocouple (deck)	0-1000°C	5.0/1.5/0.0	3-84-2	Affixed to the deck. Provides ΔT through deck (refer to #373).
319	Load Cell	0-500 kg	5.5/0.7/	3-84-1	Load cell located below deck. Coordinate indicates the center of the fuel "cradle." Load cell mounting mechanism designed such that cradle is approximately 0.3 m above deck.
320	Thermocouple	0-1000°C	5.5/1.5/2.5	3-81-2	Located above fuel cradle, just below the overhead (plume temp).
321	Thermocouple	0-1000°C	5.5/1.5/1.5	3-81-2	Located above fuel cradle, just above fuel source (flame temp).
322	Radiometer	0-50 kW/m^2	5.4/0.0/1.0	3-81-2	Installed through (flush mount) interior (starboard) bulkhead.
323	Calorimeter	0-50 kW/m^2	5.6/0.0/1.0	3-81-2	Installed through (flush mount) interior (starboard) bulkhead.
324	Infra Red Camera	N/A	8.5/1.0/1.0	3-81-1	Coordinate represents the approximate center of viewing window. Mounting bracket for NFTI installed inside escape trunk.
325	Thermocouple	0-1000°C	1.5/2.8/2.5	3-87-2	Aft thermocouple string.
326	Thermocouple	0-1000°C	1.5/2.8/2.0	3-87-2	Aft thermocouple string.
327	Thermocouple	0-1000°C	1.5/2.8/1.5	3-87-2	Aft thermocouple string.
328	Thermocouple	0-1000°C	1.5/2.8/1.0	3-87-2	Aft thermocouple string.
329	Thermocouple	0-1000°C	1.5/2.8/0.5	3-87-2	Aft thermocouple string.
330	Thermocouple	0-1000°C	1.5/2.8/0.05	3-87-2	Aft thermocouple string.

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location (x/y/z)	Location Frame No.	REMARKS
331	Bi-flow Probe	+/- 25 Pa	2.45/1.4/1.9	3-86-1	Probe is located in the approximate center of Laundry Fire Compartment Door. Mounted on "movable" bracket to facilitate personnel movement through this opening.
332	Bi-flow Probe	+/- 25 Pa	2.45/1.4/0.5	3-86-1	Probe is located in the approximate center of Laundry Fire Compartment Door. Mounted on "movable" bracket to facilitate personnel movement through this opening.
333	Thermocouple	0-1000°C	2.45/1.4/1.9	3-86-1	Shall be mounted immediately adjacent to #331.
334	Thermocouple	0-1000°C	2.45/1.4/0.5	3-86-1	Shall be mounted immediately adjacent to #332.
335	Bi-flow Probe	+/- 125 Pa	Exhaust Vent. Duct 3-87-2		Probe centered within the duct, parallel to flow, and as close as practical to the "sleeve" penetrating the ship's hull.
336	Thermocouple	0-1000°C	Exhaust Vent. Duct 3-87-2		Installed immediately adjacent to Bi-flow Probe, #335.
337	Thermocouple	0-1000°C	1.25/0.5/0.0	3-87-1	Installed in H11 opening. Located immediately adjacent to #330.
338	Bi-flow Probe	+/-25 Pa	1.25/0.5/0.0	3-87-1	Center in the opening of H11.
339	Diff. Pressure	+/-25 Pa	7.0/1.5/2.52	3-82-0	Low side to Torpedo Room (3-74-2). Located at forward thermocouple string (7.2/1.5/2.52).
AMR (3-88-2) (refer to Figure A-15)					
340	Diff. Pressure	+/- 25 Pa	7.0/1.0/1.5	3-88-2	Low side to 3-82-2 (at 1.5/2.8/2.52). Located with forward thermocouple string.
341	Thermocouple	0-1000°C	7.0/1.0/2.5	3-90-2	Forward thermocouple string.
342	Thermocouple	0-1000°C	7.0/1.0/2.0	3-90-2	Forward thermocouple string.

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
343	Thermocouple	0-1000°C	7.0/1.0/1.5	3-90-2	Forward thermocouple string.
344	Thermocouple	0-1000°C	7.0/1.0/1.0	3-90-2	Forward thermocouple string.
345	Thermocouple	0-1000°C	7.0/1.0/0.5	3-90-2	Forward thermocouple string.
346	Thermocouple (deck)	0-1000°C	7.0/2.0/2.55	3-90-2	Affixed to overhead, opposite #243.
347	Optical Density Meter	0-100%	4.0/0.6/2.5	3-91-2	Mounting bracket centered on coordinate.
348	Optical Density Meter	0-100%	4.0/0.6/1.5	3-91-2	Mounting bracket centered on coordinate.
349	Optical Density Meter	0-100%	4.0/0.6/0.5	3-91-2	Mounting bracket centered on coordinate.
350	Video Camera	N/A	1.5/2.1/1.0	3-94-2	Coordinate represents approximate location of "lens."
351	IR Camera	N/A	1.5/2.4/1.0	3-94-2	Coordinate represents approximate location of "lens."
352	O_2 Gas Sample	0-25%	7.0/2.4/2.5	3-90-2	Upper layer sample. Located at Fire Test Enclosure.
353	O_2 Gas Sample	0-25%	7.0/2.4/1.0	3-90-2	Lower layer sample. Located at Fire Test Enclosure.
354	CO Gas Sample	0-5%	7.0/2.4/2.5	3-90-2	Upper layer sample. Located at Fire Test Enclosure.
355	CO Gas Sample	0-25%	7.0/2.4/1.0	3-90-2	Lower layer sample. Located at Fire Test Enclosure.
356	CO_2 Gas Sample	0-20%	7.0/2.4/2.5	3-90-2	Upper layer sample. Located at Fire Test Enclosure.
357	CO_2 Gas Sample	0-5%	7.0/2.4/1.0	3-90-2	Lower layer sample. Located at Fire Test Enclosure.
358	Load Cell	0-300 lb	7.0/2.5/0.3	3-90-2	Load cell located below deck. Coordinate indicates the center of the fuel "cradle." Load cell mounting mechanism designed such that cradle is approximately 0.3 m above deck.

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
359	Bi-flow Probe	+/- 125 Pa	Exh. Vent Duct	3-90-2	Probe centered within exhaust duct and oriented parallel to air flow.
360	Thermocouple	0-1000°C	Exh. Vent Duct	3-90-2	Installed immediately adjacent to #359.
361	Bi-flow Probe	+/- 125 Pa	Supply Vent Duct	3-93-2	Probe centered within supply duct and oriented parallel to air flow.
362	Thermocouple	0-1000°C	Supply Vent Duct	3-93-2	Installed immediately adjacent to #361.
363	Thermocouple	0-1000°C	7.0/2.5/0.3	3-90-2	Located above fuel cradle, just above the fuel source (flame temp).
364	Thermocouple	0-1000°C	7.0/2.5/0.3	3-90-2	Located above fuel cradle, just above the fuel source (flame temp).
365	Thermocouple	0-1000°C	7.0/2.5/0.3	3-90-2	Located above fuel cradle, just above the fuel source (flame temp).
366	Thermocouple	0-1000°C	1.5/1.5/2.5	3-93-2	Aft thermocouple string.
367	Thermocouple	0-1000°C	1.5/1.5/2.0	3-93-2	Aft thermocouple string.
368	Thermocouple	0-1000°C	1.5/1.5/1.5	3-93-2	Aft thermocouple string.
369	Thermocouple	0-1000°C	1.5/1.5/1.0	3-93-2	Aft thermocouple string.
370	Thermocouple	0-1000°C	1.5/1.5/0.5	3-93-2	Aft thermocouple string.
BILGE (4-74-2) (NOTE: "Z" dimension is measured DOWN from overhead.) (refer to Figure A-16)					
371	Thermocouple (deck)	0-500°C	5.0/2.2/0.0	4-77-2	Affixed to overhead, opposite #275.
372	Thermocouple	0-500°C	5.0/2.2/1.0	4-77-2	Located 1.0 m below overhead.

INSTRUMENTATION LISTING - Submarine Ventilation Doctrine Testing (Sub 8)

Note: For coordinate system (x/y/z), measurements are from: aft bulkhead/starboard bulkhead/deck level, within each space (exempt Bridge Access Trunk and Bilge level spaces). "+" is forward, port, up. [All dimensions are in meters.] Instrumentation in shaded rows removed for test series.

Item No.	Instrument Description	Output Range	Location		REMARKS
			(x/y/z)	Frame No.	
BATTERY COMPARTMENT (4-81-2) (NOTE: "Z" dimension is measured DOWN from overhead.) (refer to Figure A-17)					
373	Thermocouple (deck)	0-500°C	5.0/1.5/0.0	4-84-2	Affixed to overhead, immediately opposite #318.
374	Thermocouple	0-500°C	5.0/1.5/1.0	4-84-2	Below #373.
375	. Diff. Pressure	+/-25 Pa	7.5/2.0/0.5	4-81-2	Low side to space 3-82-2.
BILGE (4-88-2) (NOTE: "Z" dimension is measured DOWN from overhead.) (refer to Figure A-18)					
376	Thermocouple	0-500°C	4.5/2.0/1.0	4-91-2	Air thermocouple.
TEST CONTROL ROOM					
377	Audio	N/A			Installed in Control Room.

Appendix C

Watch Bills and Protective Gear Logs

Watch Bill

Test No. Sub8_01 Date: 16 June 1997
Test Description: Class A Fire in Laundry Fire Compartment

Name	Position/Station
Caudle	MIC / Scene Leader
Rayburn	CC Cord / Control - DCCentral
Smith	Nozzleman / Hose Team I
Parkhurst	NFTI / Hose Team I
Schwind	Hoseman / Hose Team I
London	Hoseman (Plug) / Hose Team I
Fahringer	Nozzleman / Hose Team II
Dominick	NFTI / Hose Team II
Freytag	Hoseman / Hose Team II
Thompson	Hoseman (Plug) / Hose Team II
Kievit	Rapid Response Team
Kulhanek	Rapid Response Team
Richardson	Rapid Response Team
Dinwiddie	Watchstander

Protective Gear Log

Test No. Sub8_01 Date: 16 June 1997
Test Description: Class A Fire in Laundry Fire Compartment

Name	Protective Gear
Caudle	Sub Coveralls, Flashhood, Flash Gloves, OBA
Rayburn	Sub Coveralls, No Flashhood or Flash Gloves, SCBA
Smith	Nomex Coveralls, Flashhood, Fire Fighters Gloves, FFE, OBA
Parkhurst	Nomex Coveralls, Flashhood, Fire Fighters Cloves, FFE, OBA
Schwind	Sub Coveralls, Flashhood, Fire Fighters Gloves, FFE, OBA
London	Nomex Coveralls, Flashhood, Flash Gloves, OBA
Fahringer	Sub Coveralls, Flashhood, Fire Fighters Gloves, FFE, OBA
Dominick	Nomex Coveralls, Flashhood, Flash Gloves, OBA
Freytag	Sub Coveralls, 2 Flashhoods, Flash Gloves, OBA
Thompson	Nomex Coveralls, Flashhood, Flash Gloves, OBA
Kievit	Nomex Coveralls, Flashhood, Fire Fighters Gloves, SCBA
Kulhanek	Sub Coveralls, Flashhood, Flash Gloves, SCBA
Richardson	Sub Coveralls, Flashhood, Flash Gloves, SCBA
Dinwiddie	Sub Coveralls, Flash Gloves, SCBA

Watch Bill

Test No. Sub8_02 Date: 17 June 1997
Test Description: Class A Fire in AMR

Name	Position/Station
Caudle	MIC / Scene Leader
Rayburn	CC Cord / Control - DCCentral
Fahringer	Nozzleman / Hose Team I
Thompson	NFTI / Hose Team I
Dominick	Hoseman / Hose Team I
Freytag	Hoseman (Plug) / Hose Team I
Kievit	Nozzleman / Hose Team II
Kulhanek	NFTI / Hose Team II
Richardson	Hoseman / Hose Team II
Dinwiddie	Hoseman (Plug) / Hose Team II
Smith	Rapid Response Team
Schwind	Rapid Response Team
London	Rapid Response Team
Parkhurst	Watchstander

Protective Gear Log

Test No. Sub8_02 Date: 17 June 1997
Test Description: Class A Fire in AMR

Name	Protective Gear
Caudle	Sub Coveralls, Flashhood, Flash Gloves, OBA
Rayburn	Sub Coveralls, Flashhood, Flash Gloves, SCBA
Smith	Nomex Coveralls, Flashhood, Flash Gloves, SCBA
Parkhurst	Nomex Coveralls, Flashhood, Flash Gloves, SCBA
Schwind	Sub Coveralls, Flashhood, Flash Gloves, OBA
London	Flashhood, Flash Gloves, SCBA
Fahringer	Sub Coveralls, 1 Flashhood, FFE, OBA
Dominick	Nomex Coveralls, Flashhood, Fire Fighter Gloves, FFE, OBA
Freytag	Sub Coveralls, 1 Flashhood, Flash Gloves, OBA
Thompson	Nomex Coveralls, Flashhood, Fire Fighter Gloves, FFE, OBA
Kievit	Nomex Coveralls, Flashhood, Fire Fighter Gloves, FFE, OBA
Kulhanek	Sub Coveralls, Flashhood, Fire Fighter Gloves, FFE, OBA
Richardson	Sub Coveralls, Flashhood, Flash Gloves, OBA
Dinwiddie	Sub Coveralls, Flashhood, Flash Gloves, OBA

Watch Bill

Test No. Sub8_03 Date: 17 June 1997
Test Description: Class A Fire in AMR and Class A Fire in Laundry Compartment

Name	Position/Station
Caudle	MIC / Scene Leader
Rayburn	CC Cord / Control - DCCentral
Dominick	Nozzleman / Hose Team I
Freytag	NFTI / Hose Team I
Thompson	Hoseman / Hose Team I
Fahringer	Hoseman (Plug) / Hose Team I
Kulhanek	Nozzleman / Hose Team II
Kievit	NFTI / Hose Team II
Dinwiddie	Hoseman / Hose Team II
Richardson	Hoseman (Plug) / Hose Team II
Parkhurst	Rapid Response Team
Schwind	Rapid Response Team
London	Rapid Response Team
Smith	Watchstander

Protective Gear Log

Test No. Sub8_03 Date: 17 June 1997
Test Description: Class A Fire in AMR and Class A Fire in Laundry Compartment

Name	Protective Gear
Caudle	Sub Coveralls, Flashhood, Fire Fighter Gloves, OBA
Rayburn	Sub Coveralls, Flashhood, Flash Gloves, OBA
Smith	Nomex Coveralls, Flashhood, Flash Gloves, OBA
Parkhurst	Nomex, Coveralls, Flashhood, Flash Gloves, OBA
Schwind	Sub Coveralls, Flashhood, Flash Gloves, OBA
London	Nomex Coveralls, Flashhood, Flash Gloves, OBA
Fahringer	Sub Coveralls, Flashhood, Flash Gloves, OBA
Dominick	Nomex Coveralls, Flashhood, Fire Gloves, FFE, OBA
Freytag	Sub Coveralls, 1 Flashhood, Flash Gloves, FFE, OBA
Thompson	Nomex Coveralls, Flashhood, Flash Gloves, OBA
Kievit	Nomex Coveralls, Flashhood, Fire Fighter Gloves, FFE, OBA
Kulhanek	Flashhood, Fire Fighter Gloves, FFE, OBA
Richardson	Sub Coveralls, Flashhood, OBA Gloves, OBA
Dinwiddie	Sub Coveralls, Flashhood, Flash Gloves, OBA

Watch Bill

Test No. Sub8_04 Date: 18 June 1997
Test Description: Class A&B Fire in AMR

Name	Position/Station
Caudle	MIC / Scene Leader
Rayburn	CC Cord / Control - DCCentral
Dinwiddie	Nozzleman / Hose Team I
Richardson	NFTI / Hose Team I
Kievit	Hoseman / Hose Team I
Kulhanek	Hoseman (Plug) / Hose Team I
Schwind	Nozzleman / Hose Team II
London	NFTI / Hose Team II
Smith	Hoseman / Hose Team II
Parkhurst	Hoseman (Plug) / Hose Team II
Freytag	Rapid Response Team
Fahringer	Rapid Response Team
Thompson	Rapid Response Team
Dominick	Watchstander

Protective Gear Log

Test No. Sub8_04 Date: 18 June 1997
Test Description: Class A&B Fire in AMR

Name	Protective Gear
Caudle	Sub Coveralls, Flashhood, Fire Fighter Gloves, OBA
Rayburn	Sub Coveralls, Double Flashhood, Flash Gloves, EAB OBA
Smith	Nomex Coveralls, 1 Flashhood, Fire Fighter Gloves, FFE, OBA
Parkhurst	Nomex Coveralls, Flashhood, Fire Fighter Gloves, OBA
Schwind	Nomex Coveralls, Flashhood, Fire Fighter Gloves, OBA
London	Nomex Coveralls, Flashhood, Fire Fighter Gloves, FFE, OBA
Fahringer	Sub Coveralls, Flashhood, Flash Gloves, OBA (Simulated EAB)
Dominick	Nomex Coverall, Flashhood, Fire Fighter Gloves, OBA (Simulated EAB)
Freytag	Sub Coveralls, Flashhood, Flash Gloves, OBA (Simulated EAB)
Thompson	Nomex Coveralls, Flashhood, Flash Gloves, OBA
Kievit	Nomex Coveralls, Flashhood, Fire Fighter Gloves, OBA
Kulhanek	Sub Coveralls, Flashhood, Fire Fighter Gloves, OBA
Richardson	Sub Coveralls, Flashhood, OBA Gloves, FFE, OBA
Dinwiddie	Sub Coveralls, Double Flashhood, Fire Fighter Gloves, FFE, OBA

Watch Bill

Test No. Sub8_05 Date: 18 June 1997
Test Description: Class A&B Fire in AMR

Name	Position/Station
Caudle	MIC / Scene Leader
Rayburn	CC Cord / Control - DCCentral
Schwind	Nozzleman / Hose Team I
Dinwiddie	NFTI / Hose Team I
Kievit	Hoseman / Hose Team I
Kulhanek	Hoseman (Plug) / Hose Team I
Parkhurst	Nozzleman / Hose Team II
Smith	NFTI / Hose Team II
Richardson	Hoseman / Hose Team II
-------	Hoseman (Plug) / Hose Team II
Thompson	Rapid Response Team
Fahringer	Rapid Response Team
Dominick	Rapid Response Team
Freytag	Watchstander

Protective Gear Log

Test No. Sub8_05 Date: 18 June 1997
Test Description: Class A&B Fire in AMR

Name	Protective Gear
Caudle	Sub Coveralls, Flashhood, Fire Fighter Gloves, OBA
Rayburn	Sub Coveralls, Flashhood, Flash Gloves, OBA (Simulated EAB)
Smith	Nomex Coveralls, Flashhood, Fire Fighter Gloves, FFE, OBA
Parkhurst	Nomex Coveralls, Flashhood, Fire Fighter Gloves, FFE, OBA
Schwind	Nomex Coveralls, Flashhood, Fire Fighter Gloves, FFE, OBA
London	N/A
Fahringer	Sub Coveralls, Flashhood, Flash Gloves, OBA (Simulated EAB)
Dominick	Nomex Coveralls, Flashhood, Fire Fighter Gloves, OBA (Simulated EAB)
Freytag	Sub Coveralls, Flashhood, Flash Gloves, OBA (Simulated EAB)
Thompson	Nomex Coveralls, Flashhood, Flash Gloves, OBA (Simulated EAB)
Kievit	Nomex Coveralls, Flashhood, Fire Fighter Gloves, OBA
Kulhanek	Sub Coveralls, Flashhood, Fire Fighter Gloves, OBA
Richardson	Sub Coveralls, Flashhood, Flash Gloves, OBA
Dinwiddie	Sub Coveralls, 2 Flashhoods, Flash Gloves, FEE, OBA

Watch Bill

Test No. Sub8_06 Date: 19 June 1997
Test Description: Class A Fire in Laundry Fire Compartment Extending Up To Involve Wooden Wardroom Framebay Mockup

Name	Position/Station
Caudle	MIC / Scene Leader
Rayburn	CC Cord / Control - DCCentral
Richardson	Nozzleman / Hose Team I
Parkhurst	NFTI / Hose Team I
Smith	Hoseman / Hose Team I
Thompson	Hoseman (Plug) / Hose Team I
Kulhanek	Nozzleman / Hose Team II
Fahringer	NFTI / Hose Team II
London	Hoseman / Hose Team II
Freytag	Hoseman (Plug) / Hose Team II
Kievit	Rapid Response Team
Dinwiddie	Rapid Response Team
Dominick	Rapid Response Team
Schwind	Watchstander

Protective Gear Log

Test No. Sub8_06 Date: 19 June 1997
Test Description: Class A Fire in Laundry Fire Compartment Extending Up To Involve Wooden Wardroom Framebay Mockup

Name	Protective Gear
Caudle	Sub Coveralls, Flashhood, Flash Gloves, OBA
Rayburn	Sub Coveralls, Flashhood Flash Gloves, OBA (Simulated EAB)
Smith	Nomex Coveralls, 2 Flashhoods, Fire Fighter Gloves, FFE, OBA
Parkhurst	Nomex Coveralls, Double Flashhood, Fire Fighter Gloves, FFE,
Schwind	Nomex Coveralls, Flashhood, Flash Gloves, OBA
London	Nomex Coveralls, Flashhood, Fire Fighter Gloves, FFE OBA
Fahringer	Sub Coveralls, Flashhood, Fire Fighter Gloves, FEE, OBA
Dominick	Nomex Coveralls, Flashhood, Fire Fighter Gloves, OBA (Simulated EAB)
Freytag	Sub Coveralls, 2 Flashhoods, 1 Flash Gloves, OBA
Thompson	Nomex Coveralls, 2 Flashhoods, Flash Gloves, OBA
Kievit	Nomex Coveralls, Flashhood, Fire Fighter Gloves, OBA (Simulated EAB)
Kulhanek	Flashhood, Fire Fighter Gloves, OBA
Richardson	Sub Coveralls, 2 Flashhoods, Fire Fighting Gloves, FFE, OBA
Dinwiddie	Sub Coveralls, Flashhood, Flash Gloves, OBA

Watch Bill

Test No. Sub8_07 Date: 19 June 1997
Test Description: Class A Fire In Laundry Fire Compartment, Class A Fire in Laundry Fire Compartment Extending Up To Involve Wooden Wardroom Framebay Mockup, and Class A and B Fires in AMR

Name	Position/Station
Caudle	MIC / Scene Leader
Rayburn	CC Cord / Control - DCCentral
Smith	Nozzleman / Hose Team I
Schwind	NFTI / Hose Team I
Richardson	Hoseman / Hose Team I
Freytag	Hoseman (Plug) / Hose Team I
London	Nozzleman / Hose Team II
Kievit	NFTI / Hose Team II
Dinwiddie	Hoseman / Hose Team II
Dominick	Hoseman (Plug) / Hose Team II
Parkhurst	Rapid Response Team
Thompson	Rapid Response Team
Fahringer	Rapid Response Team
Kulhanek	Watchstander

Protective Gear Log

Test No. Sub8_07 Date: 19 June 1997
Test Description: Class A Fire In Laundry Fire Compartment, Class A Fire in Laundry Fire Compartment Extending Up To Involve Wooden Wardroom Framebay Mockup, and Class A and B Fires in AMR

Name	Protective Gear
Caudle	Sub Coveralls, Flashhood, Fire Fighter Gloves, OBA
Rayburn	Not within 688 enclosure this test (relocated DC Central to SHADWELL Test Control Room
Smith	Nomex Coveralls, 2 Flashhoods, Fire Fighter Gloves, FFE, OBA
Parkhurst	Nomex Coveralls, Flashhood, Flash Gloves, OBA (Simulated EAB)
Schwind	Nomex Coveralls, Flashhood, Leather Gloves, FFE, OBA
London	Nomex Coveralls, Flashhood, Fire Fighter Gloves, FFE, OBA
Fahringer	Sub Coveralls, Flashhood, Flash Gloves, OBA (Simulated EAB)
Dominick	Sub Coveralls, 2 Flashhoods, 1 Flash Gloves, OBA
Freytag	Sub Coveralls, 2 Flashhoods, 1 Flash Gloves, OBA
Thompson	Nomex Coveralls, 2 Flashhood, Flash Gloves, OBA (Simulated EAB)
Kievit	Nomex Coveralls, 2 Flashhood, Fire Fighter Gloves, FFE, OBA
Kulhanek	Sub Coveralls, Flashhood, Flash Gloves, OBA
Richardson	Sub Coveralls, Flashhood, Flash Gloves, OBA
Dinwiddie	Sub Coveralls, 2 Flashhoods, Flash Gloves, OBA

Appendix D

Sequence of Events for Tests sub8_06 and sub8_07

Sequence of Events for Tests sub8_06 and sub8_07

TIME	EVENT/ACTION
0:00	Pour Accelerant and Ignite Fire - Safety Term
2:00	Release Watchstander, "Watchstander Report Source of Smoke" - SHADWELL Test Control Room, Watchstander Reports Fire
3:00	General Alarm over 1MC - SHADEWLL Test Control Room
3:30	"Emergency Surface The Ship" - DC Central
3:30	Three (3) Blasts on Dive Alarm over 1MC - SHADWELL Test Control Room
4:00	"Prepare to Surface" over 1MC- SHADWELL Test Control Room
4:05	"Prepare to Sweep Control" over 1MC - SHADWELL Test Control Room
4:20	"ABT-13 is Open" - Man in Charge
4:40	Open VH-1, VH-2, VH-3 (Equalize Press) - DC Central
4:50	Open Bridge Upper/Lower Hatches - DC Central
6:00	"Release Rapid Response" - Fire Main is Pressurized" - SHADWELL Test Control Room
8:00	"Release Hose Teams" over 1MC
8:30	"Ship is Ready to Surface, Ready to Sweep Control" - DC Central
8:35	"Surface, Surface, Surface" over 1MC - SHADWELL Test Control Room
8:45	"Commence Control Room Sweep - SHADWELL Test Control Room
Approx. 8:50	Start L.P. blower (Start When Control Room (DC Central) is Clear and the Fire is Out)
Approx 8:50 + 1:00	Start Supply Fan - SHADWELL Test Control Room
Approx 8:50 + 2:00	Start Induction Fan - SHADWELL Test Control Room Open AMR Exhaust (Shut NAV Equipment if Desired) - SHADWELL Test Control Room

Appendix E

Summary Data Sheets

SHADWELL/688 Class Manned Fire Fighting Tests

Test: sub8_01 **Date:** 16 June 1997

I. **GENERAL DESCRIPTION:** Class A wood crib fire in Laundry Fire Compartment; fire easily accessible by fire fighters; baseline/warm-up fire.

II. **TEST SET UP**

a. Class A wood crib placed in forward portion of Laundry Fire Compartment.
b. Wood Crib: 0.61-m (2-ft) square by 22.9-cm (9-in.) high, approximately 0.5-m (1.5-ft) above deck on metal grating. Wood sticks were approximately 3.8-cm (1.5-in.) square.
c. Full tire placed on top of wood crib to create smoke.
d. Metal lockers placed inside fire compartment to make access to fire difficult.

III. **VENTILATION ALIGNMENT**

Boat initially at depth with ventilation system in Recirculation Mode. One minute after fire was called away, the ventilation fans were secured. Upon Commencing Emergency ventilate, L.P. blower exhausting out of AMR at 0.7 m^3/sec (1500 cfm), exhaust fan aligned as induction fan and operating at 2.1 m^3/sec (4500 cfm).

IV. **FIRE DEVELOPMENT**

a. Total Preburn Time Before Fire Was Called Away: 0 seconds
b. General Visibility
   1. Fire fighters reported poor visibility/heavy smoke in fire compartment and on second and third platforms.
   2. Control Room visibility reached minimum of 5% approximately 5 minutes after ignition.
   3. Ventilation configuration after fire was extinguished did not improve conditions within test area.

V. **PERSONNEL PROTECTION**

- Watchstander – Normal submarine attire, SCBA worn for safety;
- Rapid Responders – Normal submarine attire, SCBA simulating EAB, flash hood and flash gloves; and
- Hose Teams – FFE's, OBA's, flash hoods, and fire fighters gloves.

Test: sub8_01 **Date:** 16 June 1997

VI. SEQUENCE OF KEY EVENTS

TIME	EVENT
0:00	Fire Ignited
2:37	Ventilation fans secured, Fire fighting initiated (approximately)
4:00	Control Room maximum temperature 86°C (187°F)
4:12	Fire extinguished
5:00	Control Room visibility approximately 5%
10:30	CPO/Crew Mess visibility approximately 78%
11:37	Induction fan and L.P. blower operating
28:13	Test Secured

VII. SUMMARY OF FIRE FIGHTING EFFECTIVENESS

a. Total fire fighting time: approximately 4 minutes after ignition

b. Portable extinguishers used:
   1. AFFF – None
   2. CO_2 – Three
   3. PKP – None

c. Handlines Used: Primary hose pulled from Torpedo Room aft. Second hose pulled from second level passageway, down ladder into a Laundry compartment.

Total water used: approximately 265 L (70 gallons)

SHADWELL/688 Class Manned Fire Fighting Tests

Test: sub8_02 **Date:** 17 Jun 1997

I. GENERAL DESCRIPTION: Class A wood crib in Obstruction 3 in AMR between FR 89 and 90; access to fire more difficult; baseline test with more challenging fire scenario

II. TEST SET UP

a. Class A wood crib placed inside Obstruction 3 in AMR between FR 89 and 90.
b. Wood Crib: 0.61-m (2-ft) square by 22.9-cm (9-in.) high, approximately 0.3-m (1.0-ft) above deck on metal grating. Wood sticks were approximately 3.8-cm (1.5-in.) square.
c. Full tire placed on top of wood crib to create smoke.
d. Access to fire restricted by metal sides of Obstruction 3. Obstructions 1 and 2 limit compartment access.

III. VENTILATION ALIGNMENT

Boat initially at depth with ventilation system in Recirculation Mode. One minute after fire was called away, the ventilation fans were secured. Upon Commencing Emergency ventilate, L.P. blower exhausting out of AMR at 0.7 m^3/sec (1500 cfm), Exhaust Fan aligned as Induction Fan and operating at 2.1 m^3/sec (4500 cfm).

IV. FIRE DEVELOPMENT

a. Total Preburn Time Before Fire Was Called Away: 0 seconds
b. General Visibility
   1. Fire fighters reported poor visibility/heavy smoke in fire compartment and on second and third platforms.
   2. Control room visibility reached minimum of 0% approximately 7 minutes after ignition.
   3. Ventilation configuration after fire was extinguished did not improve conditions on second and third platforms.

V. PERSONNEL PROTECTION

- Watchstander - Normal submarine attire, SCBA worn for safety;
- Rapid Responders - Normal submarine attire, SCBA simulating EAB, flash hood and flash gloves; and
- Hose Teams – FFE's, OBA's, flash hoods, and fire fighters gloves.

Test: sub8_02 **Date:** 17 June 1997

VI. SEQUENCE OF KEY EVENTS

TIME	EVENT
0:00	Fire Ignited
5:15	Control Room maximum temperature 115°C (239°F)
5:30	Control Room visibility approximately 10%
6:13	Ventilation fans secured, Fire fighting initiated (approximately)
6:45	Control Room visibility reached minimum of approximately 2%
16:05	Fire extinguished
19:52	Induction fan and L.P. blower operating, Control Room visibility improved to approximately 7%
33:52	Test secured

VII. SUMMARY OF FIRE FIGHTING EFFECTIVENESS

a. Total fire fighting time: approximately 16 minutes

b. Portable extinguishers used:
   1. AFFF - two (one was water extinguisher simulating an AFFF extinguisher)
   2. CO_2 - none
   3. PKP - one

c. Handlines Used: Primary hose pulled from Torpedo Room Aft; Second hose pulled from second platform passageway, down aft scuttle in CPO/Crew Mess.

Total water used: 2,555 L (675 gal)

SHADWELL/688 Class Manned Fire Fighting Tests

Test: sub8_03 **Date:** 17 June 1997

I. **GENERAL DESCRIPTION:** One class A wood crib fire in Laundry Fire Compartment and second class A wood crib inside Obstruction 3 in AMR; represents multiple source fire scenario.

II. **TEST SET UP**

Laundry Fire :

a. Class A wood crib placed in forward portion of Laundry Fire Compartment
b. Wood Crib: 0.61-m (2-ft) square by 22.9-cm (9-in.) high, approximately 0.5-m (1.5-ft) above deck on metal grating. Wood sticks were approximately 3.8-cm (1.5-in.) square.
c. Full tire placed on top of wood crib to create smoke.
d. Metal lockers placed inside fire compartment to make access difficult.

Machinery Room Fire:

e. Class A wood crib placed inside Obstruction 3 in AMR between FR 89 and 90
f. Wood Crib: 0.61-m (2-ft) square by 22.9-cm (9-in.) high, approximately 0.3-m (1.0-ft) above deck on metal grating. Wood sticks were approximately 3.8-cm (1.5-in.) square.
g. Full tire placed on top of wood crib to create smoke.
h. Access to fire restricted by metal sides of Obstruction 3.

III. **VENTILATION ALIGNMENT**

Boat initially at periscope depth with ventilation system in Recirculation Mode. One minute after fire was called away, the ventilation fans were secured. Upon Commencing Emergency Ventilate, L.P. blower exhausting out of AMR at 0.7 m^3/sec (1500 cfm), exhaust fan aligned as induction fan and operating at 2.1 m^3/sec (4500 cfm), and supply fan operating at 3.0 m^3/sec (6300 cfm).

IV. **FIRE DEVELOPMENT**

a. Total Preburn Time Before Fire Was Called Away: approximately 90 seconds
b. General Visibility
    1. Fire fighters reported heavy smoke on second and third platforms.
    2. Control Room visibility 10% at approximately 3.5 minutes after ignition.
    3. Control Room visibility decreased to 0% at approximately 5 minutes after ignition and recovered to 10% at approximately 32 minutes after ignition.
    4. Ventilation configuration after fire was extinguished did not significantly improve conditions throughout test area.

Test: sub8_03 **Date:** 17 June 1997

IV. PERSONNEL PROTECTION

- Watchstander – Normal submarine attire, SCBA worn for safety;
- Rapid Responders – Normal submarine attire, SCBA simulating EAB, flash hood and flash gloves; and
- Hose Teams – FFE's, OBA's, flash hoods, and fire fighters gloves.

VI. SEQUENCE OF KEY EVENTS

TIME	EVENT
0:00	Fire Ignited
3:30	Control Room visibility 10%
5:00	Control Room visibility approximately 0%
5:04	Ventilation fans secured, Fire fighting initiated (approximately)
7:00	Control Room maximum temperature approximately 121°C (250°F)
10:09	Fire in Laundry extinguished
22:14	Fire in Machinery Room extinguished
23:24	Induction fan and L.P. blower operating
33:04	Test secured

VII. SUMMARY OF FIRE FIGHTING EFFECTIVENESS

a. Total fire fighting time: approximately 22 minutes

b. Portable extinguishers used:
   1. AFFF - one
   2. CO_2 - none
   3. PKP - three

c. Handlines Used: Primary hose pulled from Torpedo Room aft; Second hose pulled from second level passageway, down ladder into Laundry space.

Total water used: 2,449 L (647 gal)

SHADWELL/688 Class Manned Fire Fighting Tests

Test: sub8_04 **Date:** 18 June 1997

I. **GENERAL DESCRIPTION:** Class B diesel pan fire in Fire Test Enclosure in AMR and Class A wood crib in Obstruction 3 in AMR between FR 89 and 90; represents multiple fire source and type fire scenario.

II. **TEST SET UP**

Class B Fire Source:

a. 0.51-m (20-in.) diameter pan fire filled with diesel fuel located in the Fire Test Enclosure in AMR. A small amount of heptane added to the diesel as an accelerant to ignite the fire. Fire size was approximately 350 kW (332 BTU/sec).

b. Framebay directly above fire source directs smoke to first platform, discharging into NAV Equipment Room.

Class A Fire Source:

c. Class A wood crib placed inside Obstruction 3 in AMR between FR 89 and 90.

d Wood Crib: 0.61-m (2-ft) square by 22.9-cm (9-in.) high, approximately 0.3-m (1.0-ft) above deck on metal grating. Wood sticks were approximately 3.8-cm (1.5-in.) square.

e. Full tire placed on top of wood crib to create smoke.

f. Access to fire restricted by metal sides of Obstruction 3.

III. **VENTILATION ALIGNMENT**

Boat initially at periscope depth with ventilation system in Recirculation Mode. One minute after fire was called away, the ventilation fans were secured. Upon Commencing Emergency Ventilate, L.P. blower exhausting out of NAV Equipment Room at 0.7 m^3/sec (1500 cfm). Once at surface and prepare to sweep the Control Room, the bridge hatch was opened. The supply fan was operated after the fire was extinguished at 3.0 m^3/sec (6300 cfm).

III. **FIRE DEVELOPMENT**

a. Total Preburn Time Before Fire Was Called Away: 2.5 minutes

b. General Visibility

1. Fire fighters reported poor visibility/heavy smoke in AMR and throughout third platform.
2. Control Room visibility reached 10% approximately 4.5 minutes after ignition.
3. Control Room visibility reached 0% visibility at 9 minutes, remained at 0% for approximately 1 minute, and began to improve to better than 83%.
4. Ventilation alignment, specifically the opening of the bridge hatch to weather, significantly improved visibility conditions throughout the boat.

Test: sub8_04 **Date:** 18 June 1997

IV. PERSONNEL PROTECTION

- Watchstander – Normal submarine attire, SCBA worn for safety;
- Rapid Responders – Normal submarine attire, SCBA simulating EAB, flash hood and flash gloves; and
- Hose Teams – FFE's, OBA's, flash hoods, and fire fighters gloves.

V. SEQUENCE OF KEY EVENTS

TIME	EVENT
0:00	Fire Ignited
4:55	Ventilation fans secured, Fire fighting initiated (approximately)
5:00	Control Room visibility approximately 10%.
	Control Room reaches peak temperature of 112°C (234°F).
9:00	Control Room visibility 0%
13:17	L.P. blower out of NAV Equipment Room operating
14:22	Bridge hatch open, Class B fire extinguished
15:00	Control Room temperature reduced to approximately 60°C (140°F)
19:10	Class A Fire extinguished
21:28	Supply fan operating
34:37	Test secured

VI. SUMMARY OF FIRE FIGHTING EFFECTIVENESS

a. Total fire fighting time: approximately 19 minutes

b. Portable extinguishers used:
   1. AFFF - two
   2. CO_2 - none
   3. PKP - two (one PKP portable did not operate)

c. Handlines Used: Primary hose pulled from Torpedo Room aft. Second hose pulled from Torpedo Room forward

Total water used: 852 L (225 gal)

SHADWELL/688 Class Manned Fire Fighting Tests

Test: sub8_05 **Date:** 18 Jun 1997

I. **GENERAL DESCRIPTION:** Class B diesel pan fire in Fire Test Enclosure in AMR and Class A wood crib in Obstruction 3 in AMR between FR 89 and 90; represents multiple fire source and type fire scenario.

II. **TEST SET UP**

Class B Fire Source:

a. 0.51-m (20-in.) diameter pan fire filled with diesel fuel located in the Fire Test Enclosure in AMR. A small amount of heptane added to the diesel as an accelerant to ignite the fire. Fire size was approximately 350 kW (332 BTU/sec).

b. Framebay directly above fire source directs smoke to first platform, discharging into NAV Equipment Room.

Class A Fire Source:

c. Class A wood crib placed inside Obstruction 3 in AMR between FR 89 and 90.

d Wood Crib: 0.61-m (2-ft) square by 22.9-cm (9-in.) high, approximately 0.3-m (1.0-ft) above deck on metal grating. Wood sticks were approximately 3.8-cm (1.5-in.) square.

e. Full tire placed on top of wood crib to create smoke.

f. Access to fire restricted by metal sides of Obstruction 3.

III. **VENTILATION ALIGNMENT**

Boat initially at periscope depth with ventilation system in Recirculation Mode. One minute after fire was called away, the ventilation fans were secured. Upon Commencing Emergency Ventilate, L.P. blower exhausting out of NAV Equipment Room at 0.7 m^3/sec (1500 cfm), exhaust fan aligned as induction fan and operating at 2.1 m^3/sec (4500 cfm). Once at surface and prepare to sweep the Control Room, the bridge hatch was opened. The supply fan was operated after the fire was extinguished at 3.0 m^3/sec (6300 cfm).

IV. **FIRE DEVELOPMENT**

a. Total Preburn Time Before Fire Was Called Away: 90 seconds

b. General Visibility

1. Fire fighters reported poor visibility/heavy smoke in AMR and throughout third platform.
2. Control Room visibility reached 10% approximately 8 minutes after ignition.
3. Control Room visibility significantly improved once the bridge hatch was opened and the supply fan was operating.
4. Ventilation alignment, specifically the opening of the bridge hatch to weather, and the use of the supply fan significantly improved visibility conditions throughout the boat.

Test: sub8_05 **Date:** 18 June 1997

IV. PERSONNEL PROTECTION

- Watchstander – Normal submarine attire, SCBA worn for safety;
- Rapid Responders – Normal submarine attire, SCBA simulating EAB, flash hood and flash gloves; and
- Hose Teams – FFE's, OBA's, flash hoods, and fire fighters gloves.

V. SEQUENCE OF KEY EVENTS

TIME	EVENT
0:00	Fire Ignited
4:00	Control Room temperatures peak at approximately 102°C (216°F)
4:47	Fire fighting initiated (approximately)
9:00	Control room visibility approximately 2%
10:20	Both fires extinguished
12:47	Bridge hatch opened, L.P. blower operating out of NAV Equipment Room at 1500 cfm
13:25	Supply fan on at 6300 cfm, Control Room visibility immediately improved to 73%; Control Room temperature down to approximately 52°C (126°F)
14:35	Induction fan on at 4500 cfm
22:00	L.P. blower exhaust terminal switched from NAV Equipment Room to AMR
28:10	Test secured

VI. SUMMARY OF FIRE FIGHTING EFFECTIVENESS

a. Total fire fighting time: approximately 10 minutes

b. Portable extinguishers used:
   1. AFFF - three
   2. CO_2 - none
   3. PKP - one

c. Handlines Used: Primary hose pulled from Torpedo Room aft. Second hose pulled from Torpedo Room forward

Total water used: 132 L (35 gal)

SHADWELL/688 Class Manned Fire Fighting Tests

Test: sub8_06 **Date:** 19 June 1997

I. **GENERAL DESCRIPTION:** Multi-level fire initiated with a Class A wood crib in a metal cabinet in the Laundry Fire compartment; fire involved the Wardroom framebay directly above wood crib; framebay filled with Class A materials. Fire scenario presents a multi-level fire which traveled up into Control Room/DC Central.

II. **TEST SET UP**

Half-size wood crib:

a. Half-size Class A wood crib placed in top compartment of metal cabinet, approximately 1.5-m (5-ft) above deck. Half of the top of the cabinet was removed to allow flames to escape.

b. Half size Wood crib: 0.61-m (2-ft) long x 0.5-m (1-ft) wide by 22.9-cm (9-in.) high, approximately 15.2-cm (6-in). Wood sticks were approximately 3.8-cm (1.5-in.) square.

c. Loosely placed excelsior was piled on top of the cabinet, directly below the overhead opening to the framebay, to facilitate flame spread into the framebay.

Framebay fuel package:

d. Existing metal framebay removed and replaced with wooden mockup.

e. Inside the wooden framebay, on second platform deck, was stacked 0.61-m (2-ft) and 0.5-m (1-ft) wood sticks, 7.6-cm (3-in.) wide strips of rubber, crumpled newspaper, and excelsior. Wood sticks were approximately 3.8-cm (1.5-in.) square.

III. **VENTILATION ALIGNMENT**

Boat initially at periscope depth with ventilation system in Recirculation Mode. One minute after fire was called away, the ventilation fans were secured. Once at surface and preparing to sweep the Control Room, L.P. blower exhausting out of NAV Equipment Room at 0.7 m^3/sec (1500 cfm) and bridge hatch opened. One minute later, the supply fan was operated at 3.0 m^3/sec (6300 cfm). One minute after supply fan operating, the exhaust fan aligned as induction fan was operating at 2.1 m^3/sec (4500 cfm).

IV. **FIRE DEVELOPMENT**

a. Total Preburn Time Before Fire Was Called Away: 2 minutes

b. Door to Laundry Fire Compartment locked to slow access to seat of fire

c. General Visibility

1. Fire fighters reported heavy smoke/ poor visibility on third platform
2. Control Room visibility reached 10% at approximately 8 minutes.
3. Control Room and third platform visibility significantly improved once bridge hatch opened and ventilation commenced.

Test: sub8_06 **Date:** 19 Jun 1997

V. PERSONNEL PROTECTION

- Watchstander – Normal submarine attire, SCBA worn for safety;
- Rapid Responders – Normal submarine attire, SCBA simulating EAB, flash hood and flash gloves; and
- Hose Teams – FFE's, OBA's, flash hoods, and fire fighters gloves.

VI. SEQUENCE OF KEY EVENTS

TIME	EVENT
0:00	Fire Ignited
5:25	Ventilation fans secured
6:00	Fire fighting initiated (approximately)
7:30	Control Room temperature peaked at 205°C (401°F)
8:57	Crowbar requested to gain entry into Laundry Fire Compartment
9:45	Control Room visibility reached 0%
10:00	Control Room temperature reduced to approximately 80°C (176°F)
14:50	Fires extinguished
15:17	Bridge Hatch opened, L.P. blower operating
17:02	Supply fan operating
20:00	Control room visibility increased from 25% to 82% since ventilation commenced
21:31	Induction fan operating
32:41	Test secured

VII. SUMMARY OF FIRE FIGHTING EFFECTIVENESS

a. Total fire fighting time: approximately 15 minutes

b. Access to Laundry Fire Compartment restricted by locked Laundry room door

c. Portable extinguishers used:
   1. AFFF - two (one was water extinguisher simulating an AFFF extinguisher)
   2. CO_2 - none
   3. PKP - two

d. Handlines Used: Primary hose pulled from Torpedo Room aft for fire in Laundry. Secondary hose for framebay fire in Wardroom pulled from second level passageway.

Total water used: 182 L (42 gal)

SHADWELL/688 Class Manned Fire Fighting Tests

Test: sub8_07 **Date:** 19 Jun 1997

I. **GENERAL DESCRIPTION:** Multiple fires, multi-level fire scenario. Class A wood crib fire in Laundry Fire Compartment forward, Class A wood crib fire in Laundry Fire Compartment in Metal cabinet extending to wooden framebay on second level, Class A wood crib in AMR, and Class B fire in AMR Fire Test Enclosure.

II. **TEST SET UP**

a. Wood Crib in Laundry fire compartment forward as described in Test sub8_01
b. Wood crib in Laundry fire compartment aft/framebay as described in Test sub8_06
c. Class A & B fire in AMR as described in Test sub8_04

III. **Ventilation Alignment**

Boat initially at periscope depth with ventilation system in Recirculation Mode. One minute after fire was called away, the ventilation fans were secured. Once at surface and preparing to sweep the Control Room, L.P. blower exhausting out of NAV Equipment Room at 0.7 m^3/sec (1500 cfm) and bridge hatch opened. One minute later, the supply fan was operated at 3.0 m^3/sec (6300 cfm). One minute after supply fan operating, the exhaust fan aligned as Induction Fan was operating at 2.1 m^3/sec (4500 cfm).

IV. **FIRE DEVELOPMENT**

a. Total Preburn Time Before Fire Was Called Away: approximately 2 minutes
b. General Visibility
    1. Fire fighters reported poor visibility on third platform
    2. Control Room visibility reached 10% at 5 minutes
    3. Control Room and third platform visibility significantly improved once ventilation commenced.

V. **PERSONNEL PROTECTION**

- Watchstander – Normal submarine attire, SCBA worn for safety;
- Rapid Responders – Normal submarine attire, SCBA simulating EAB, flash hood and flash gloves; and
- Hose Teams – FFE's, OBA's, flash hoods, and fire fighters gloves.

Test: sub8_07 **Date:** 19 Jun 1997

VI. SEQUENCE OF KEY EVENTS

TIME	EVENT
0:00	Fire Ignited
4:06	Ventilation fans secured
5:00	Control room visibility approx. 10%, peak temperature approx. 92°C (198°F)
6:00	Fire fighting initiated (approximately)
7:00	Control Room temperature peaked at 190°C (374°F)
9:01	Fires extinguished
10:00	Control Room visibility approx. 0%, maximum temperature approx. 80°C (176°F)
10:21	Bridge hatch opened
10:43	L.P. blower operating
12:14	Supply fan operating
13:14	Induction fan operating

VII. SUMMARY OF FIRE FIGHTING EFFECTIVENESS

a. Total fire fighting time: approximately 9 minutes

b. Class A wood crib in metal cabinet/wooden framebay fire did not light. Metal cover over top of Obstruction 3 not installed, making extinguishment easier, Class B fire in AMR did not ignite.

c. Portable extinguishers used:
   1. AFFF - one
   2. CO_2 - none
   3. PKP - two

d. Handlines Used: 1.9-cm (0.75-in.) hose from second platform passageway pulled to Laundry fire, 1.9-cm (0.75-in.) hose from CPO/Crew Mess pulled to AMR fire. Primary 3.8-cm (1.5-in.) hose pulled from Torpedo room aft. Second 3.8-cm (1.5-in.) hose pulled from Torpedo room forward. Both 3.8-cm (1.5-in.) hoses charged but not used for fire fighting, only reflash watch. Hose reels extinguished fires.

Total water used: 534 L (141 gal)

Appendix F

Data From Representative Test (Test sub8_04)

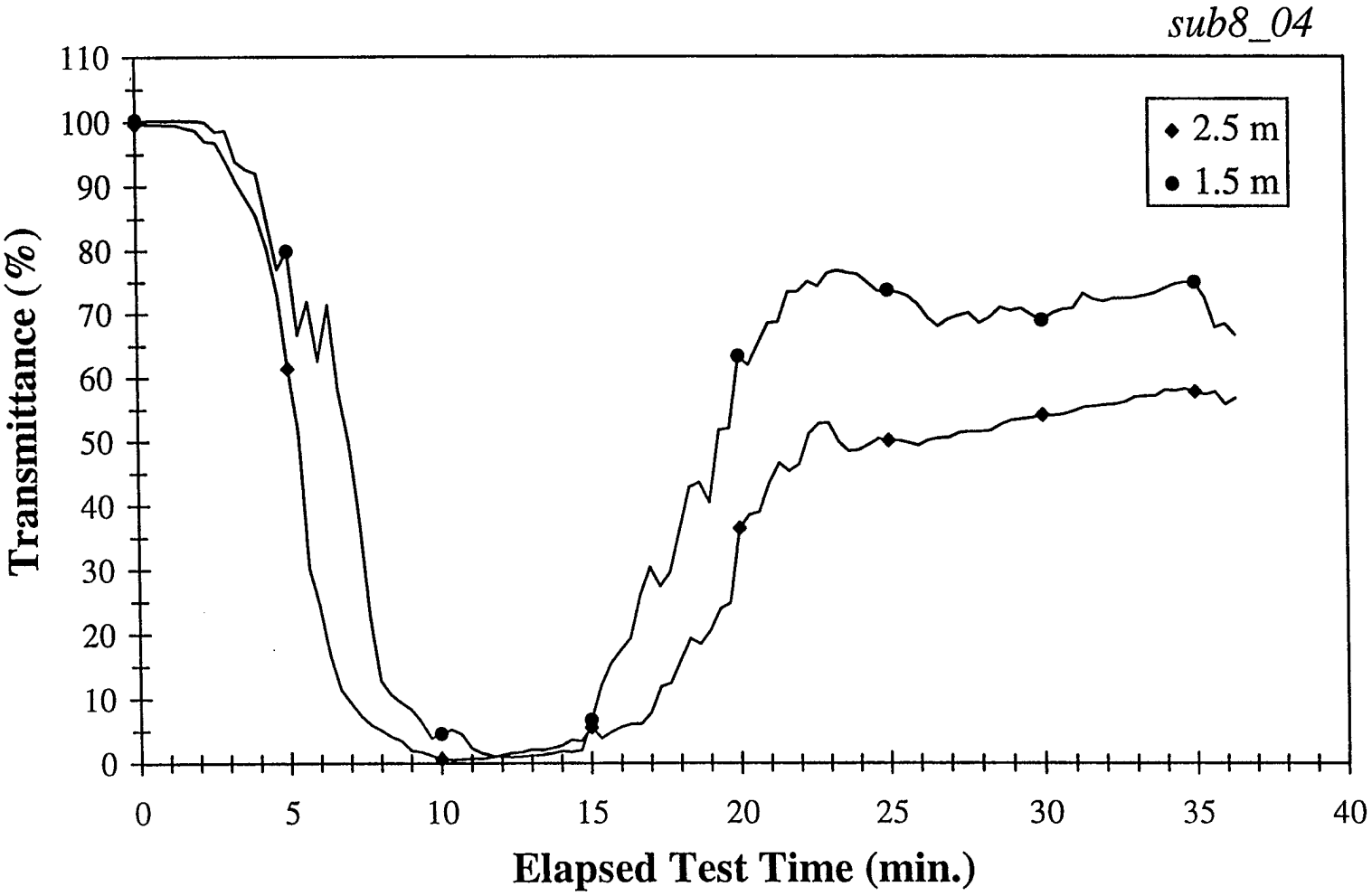

Fig. F1 – Combat Systems visibility

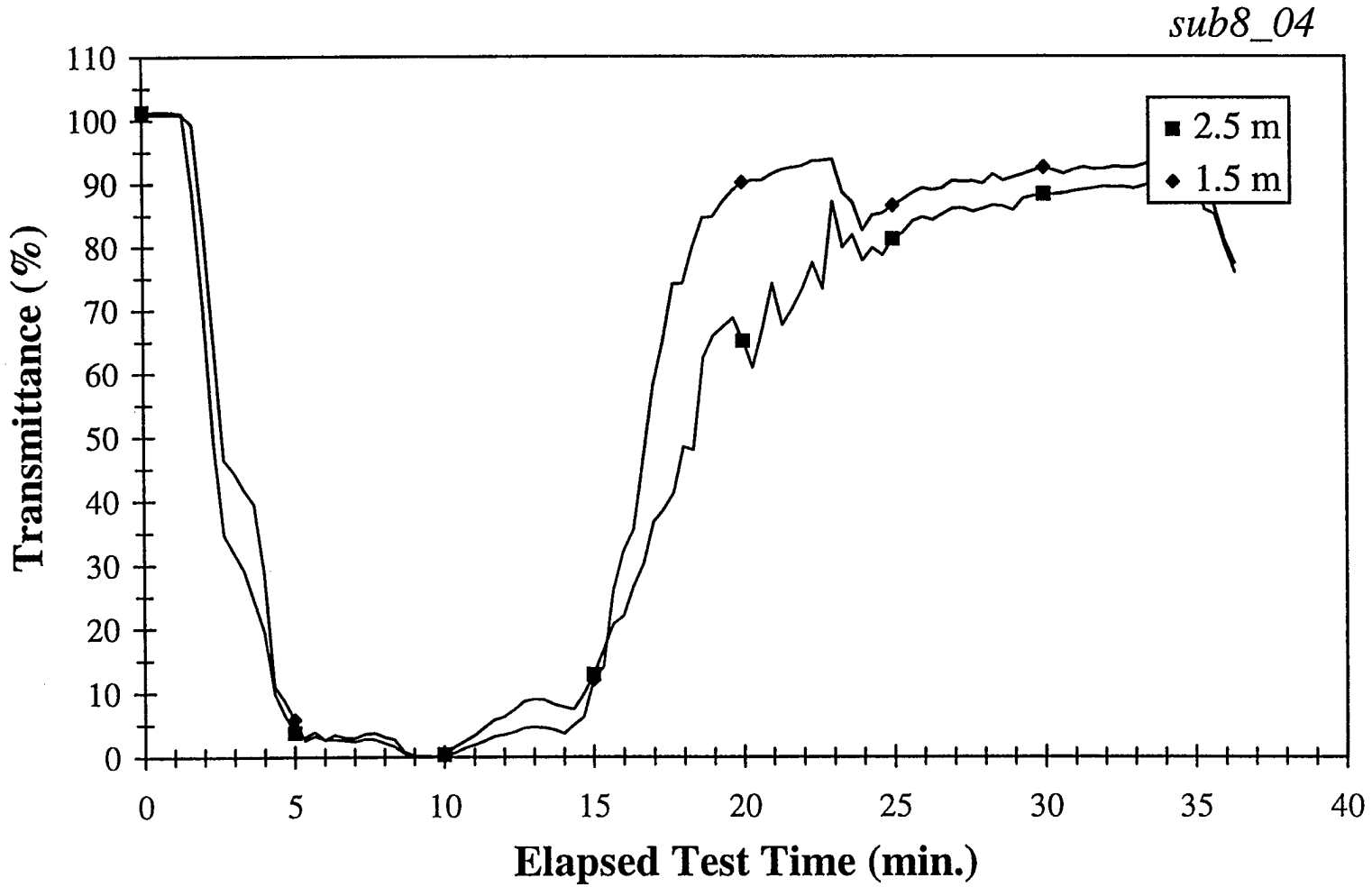

Fig. F2 – Control Room visibility

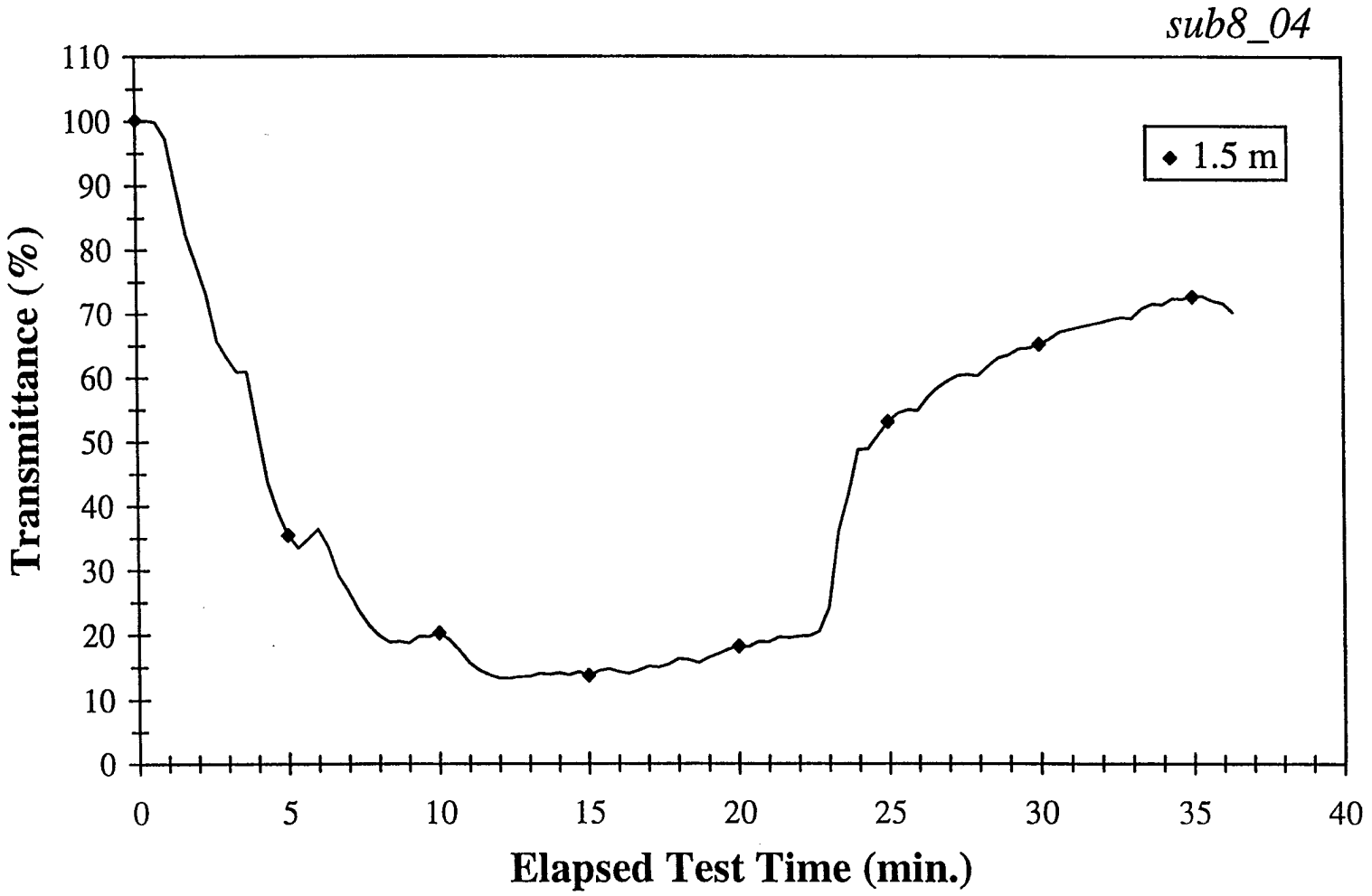

Fig. F3 – Fan Room visibility

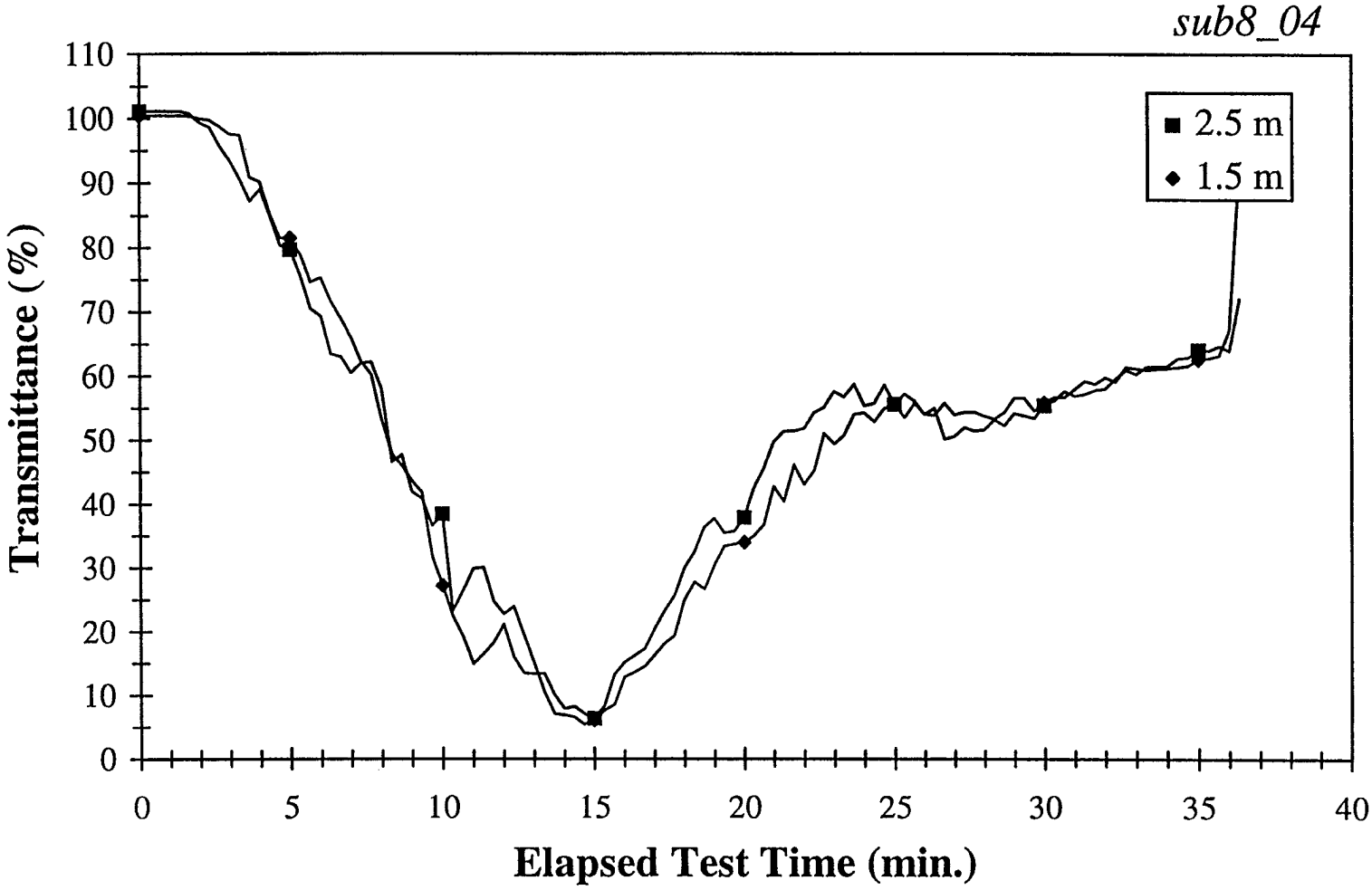

Fig. F4 – Crew Living visibility

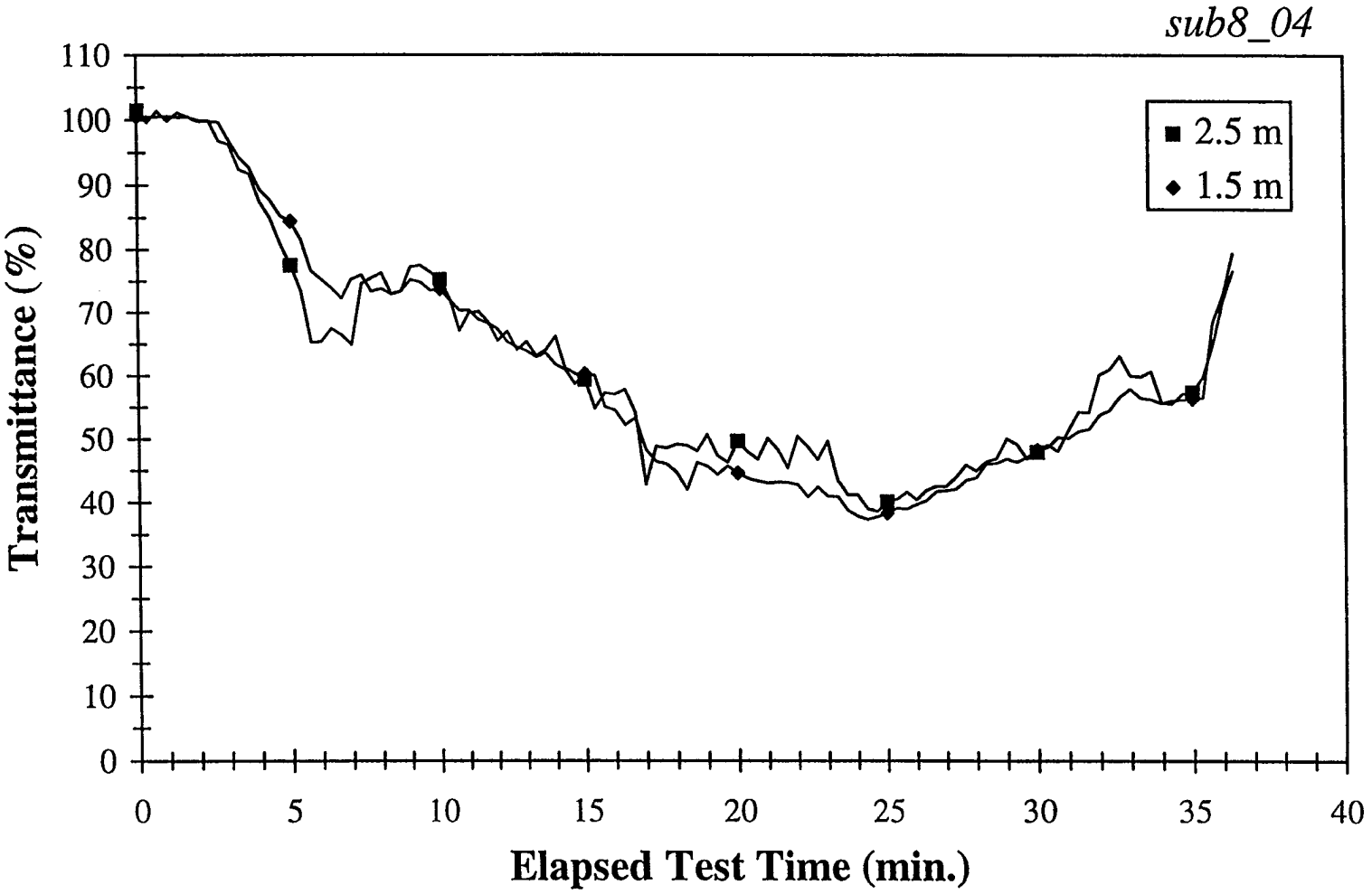

Fig. F5 – Wardroom visibility.

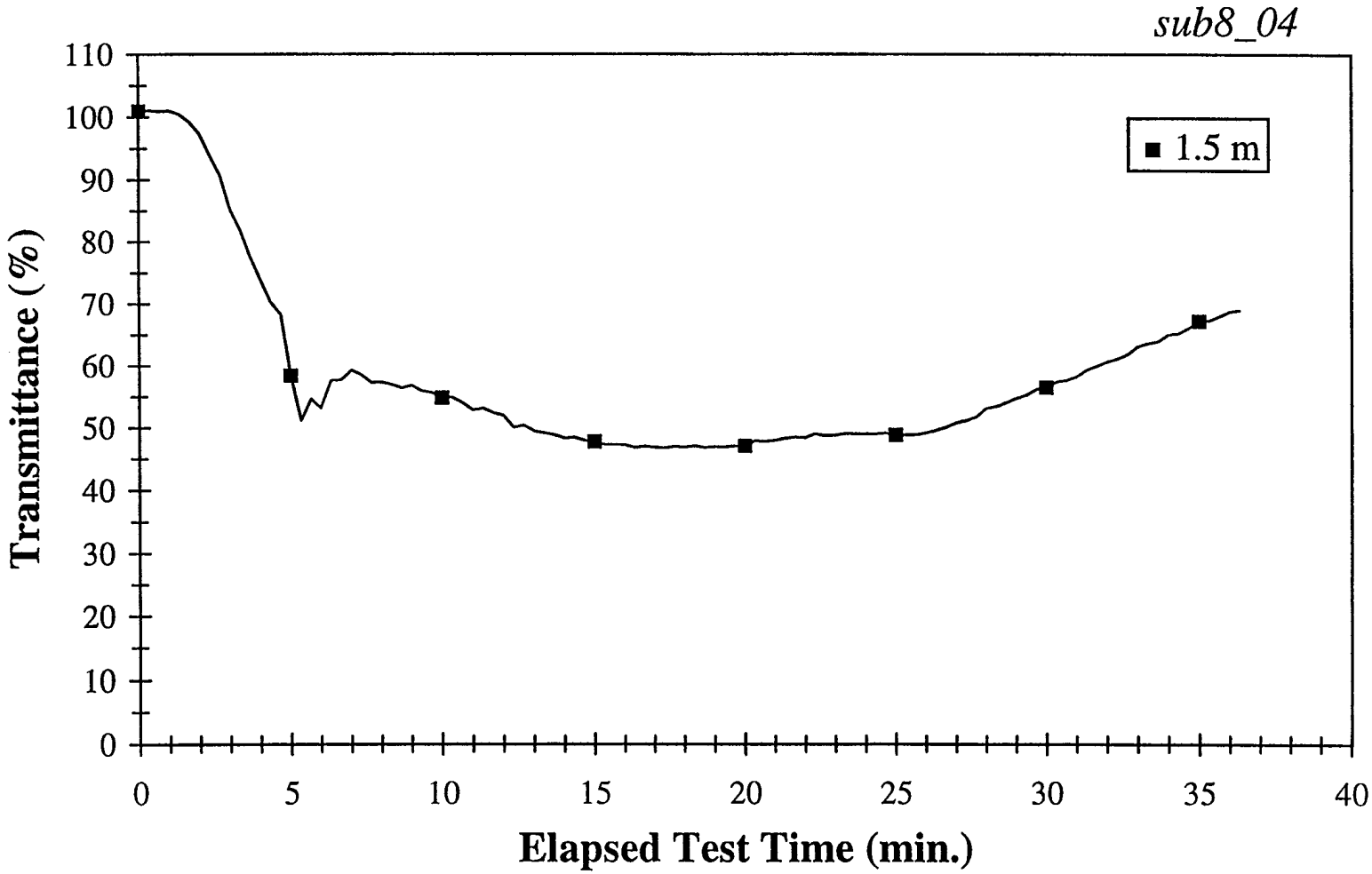

Fig. F6 – CPO/Crew Mess visibility

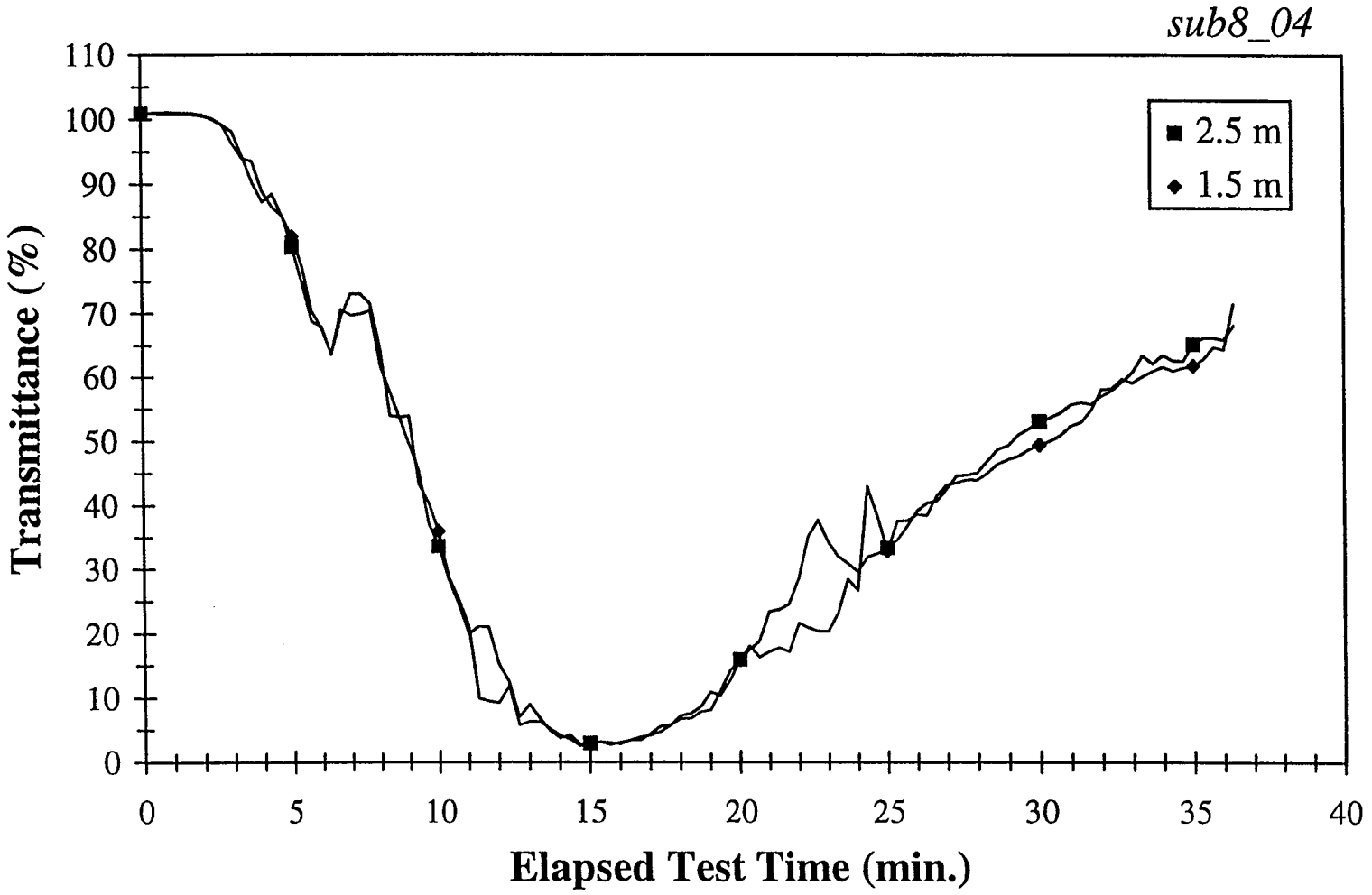

Fig. F7 – Torpedo Room visibility

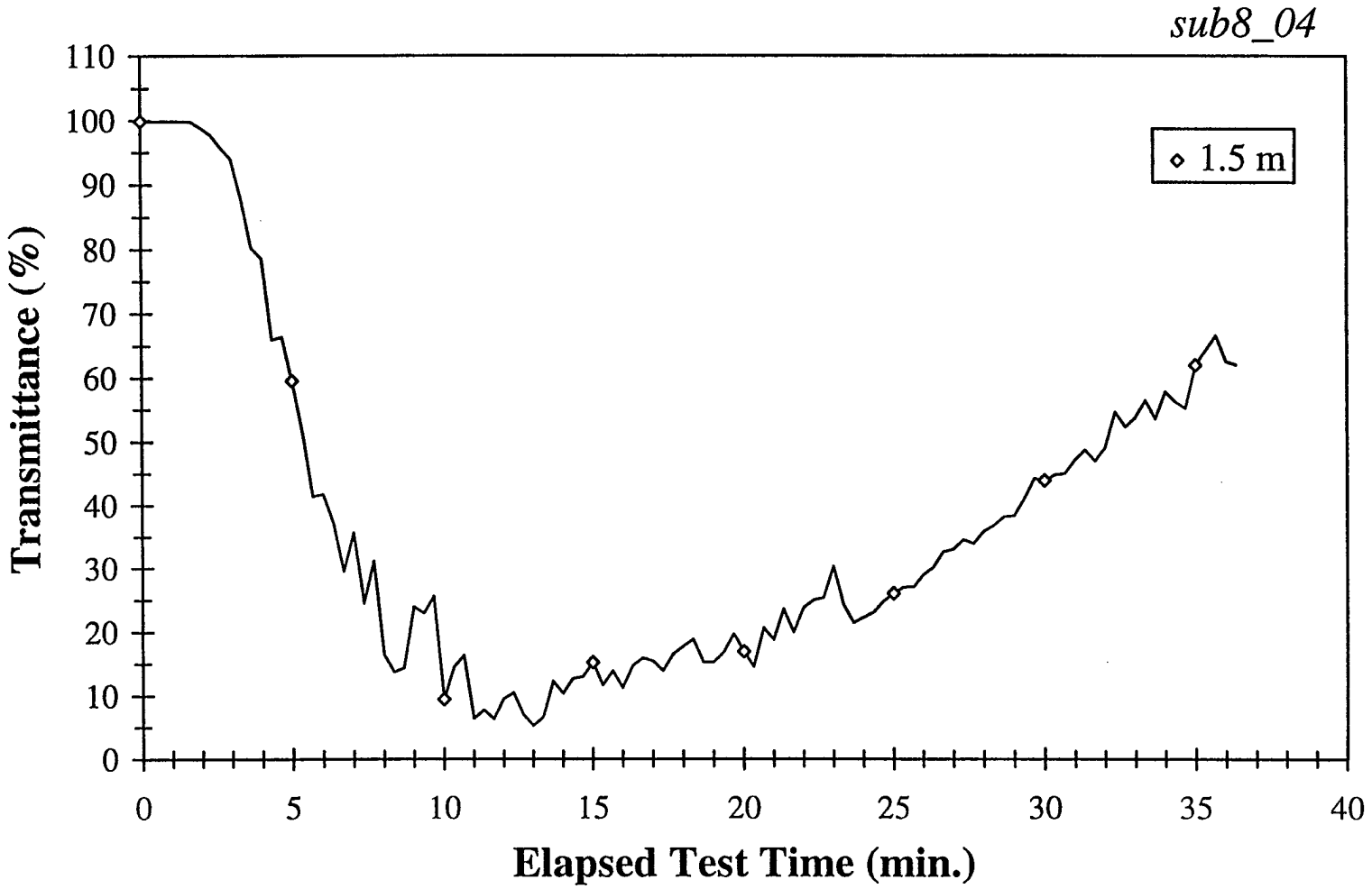

Fig. F8 – Laundry visibility

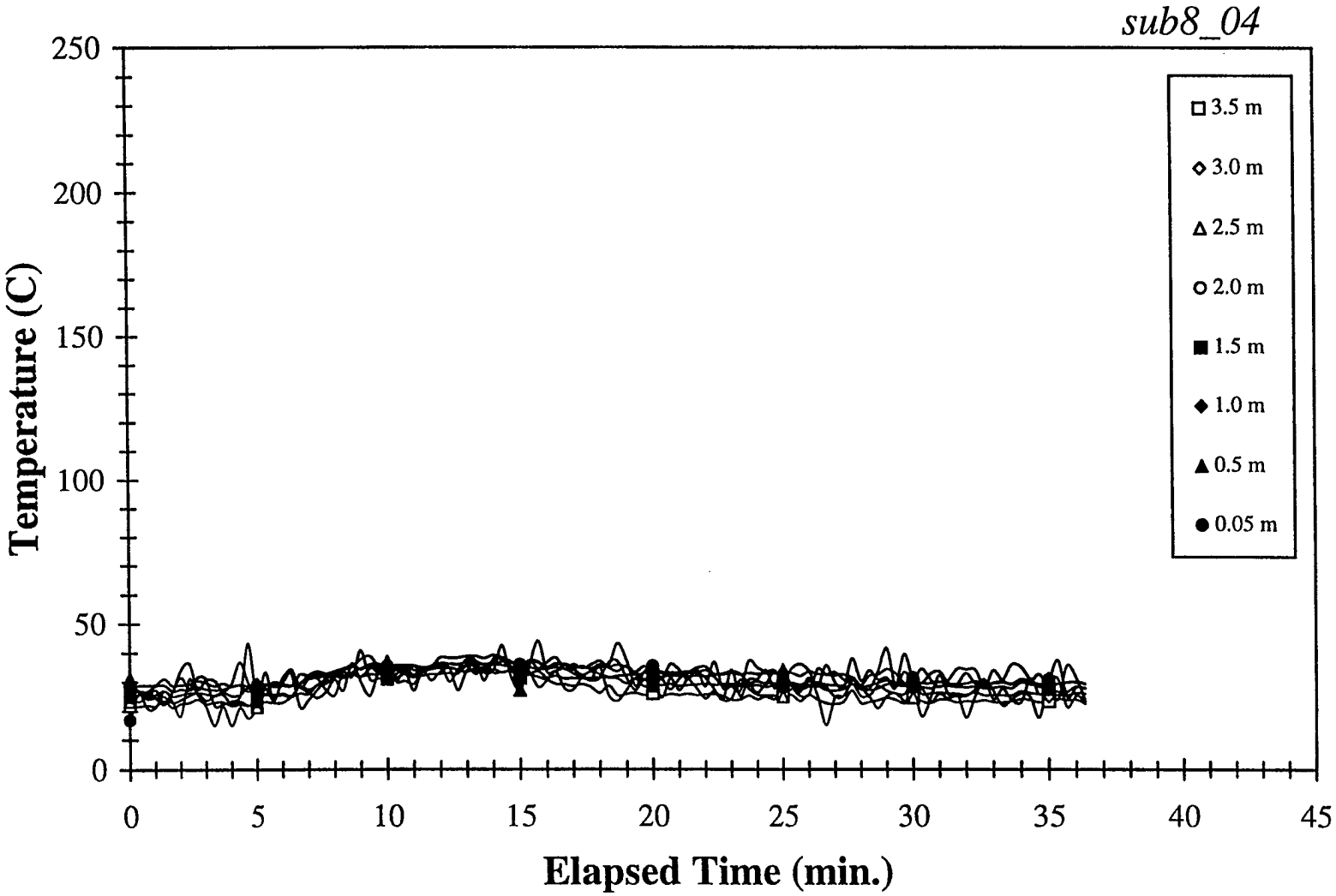

Fig. F9 – Combat Systems – Forward TC Tree

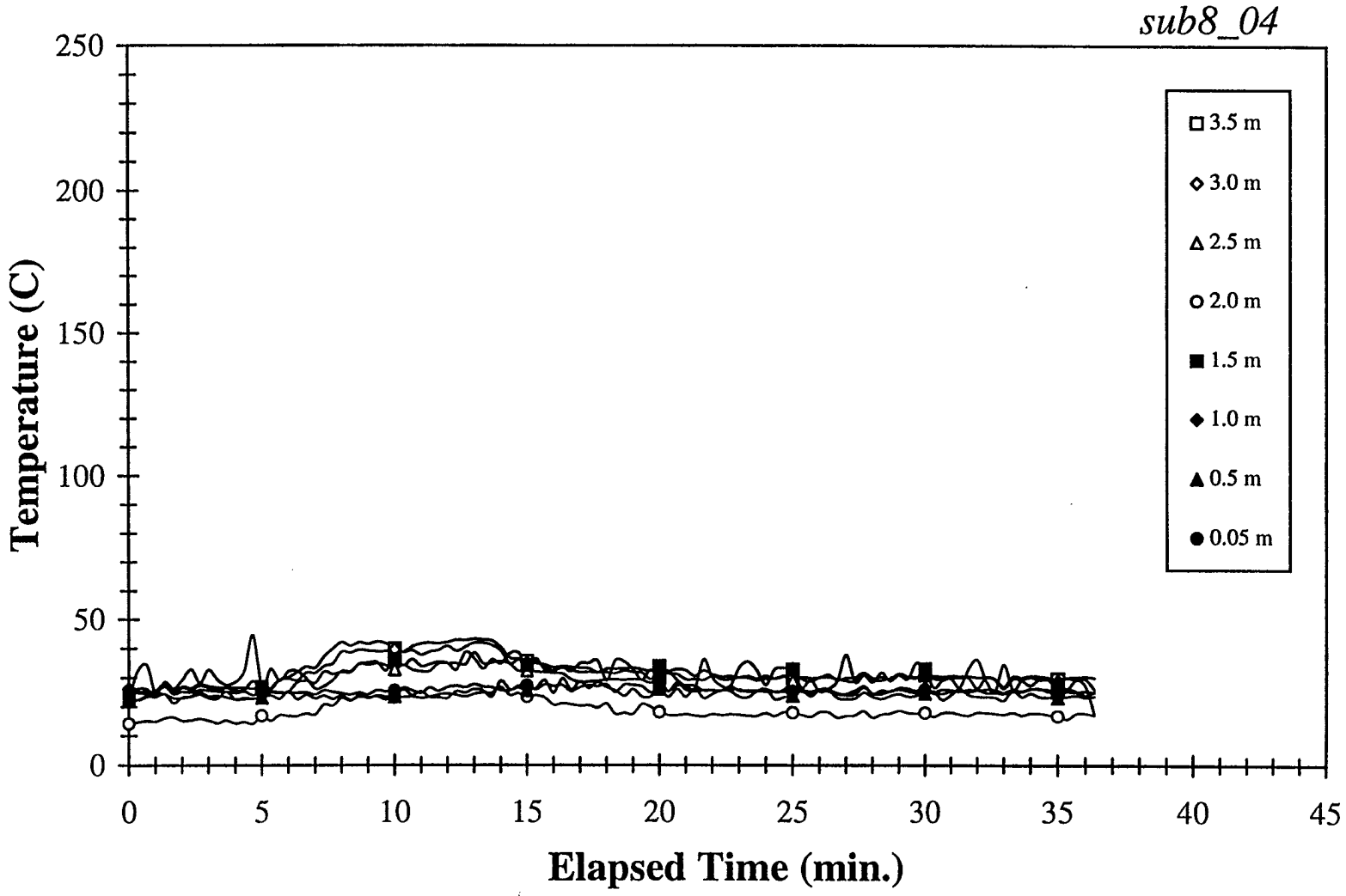

Fig. F10 – Combat Systems – Aft TC Tree

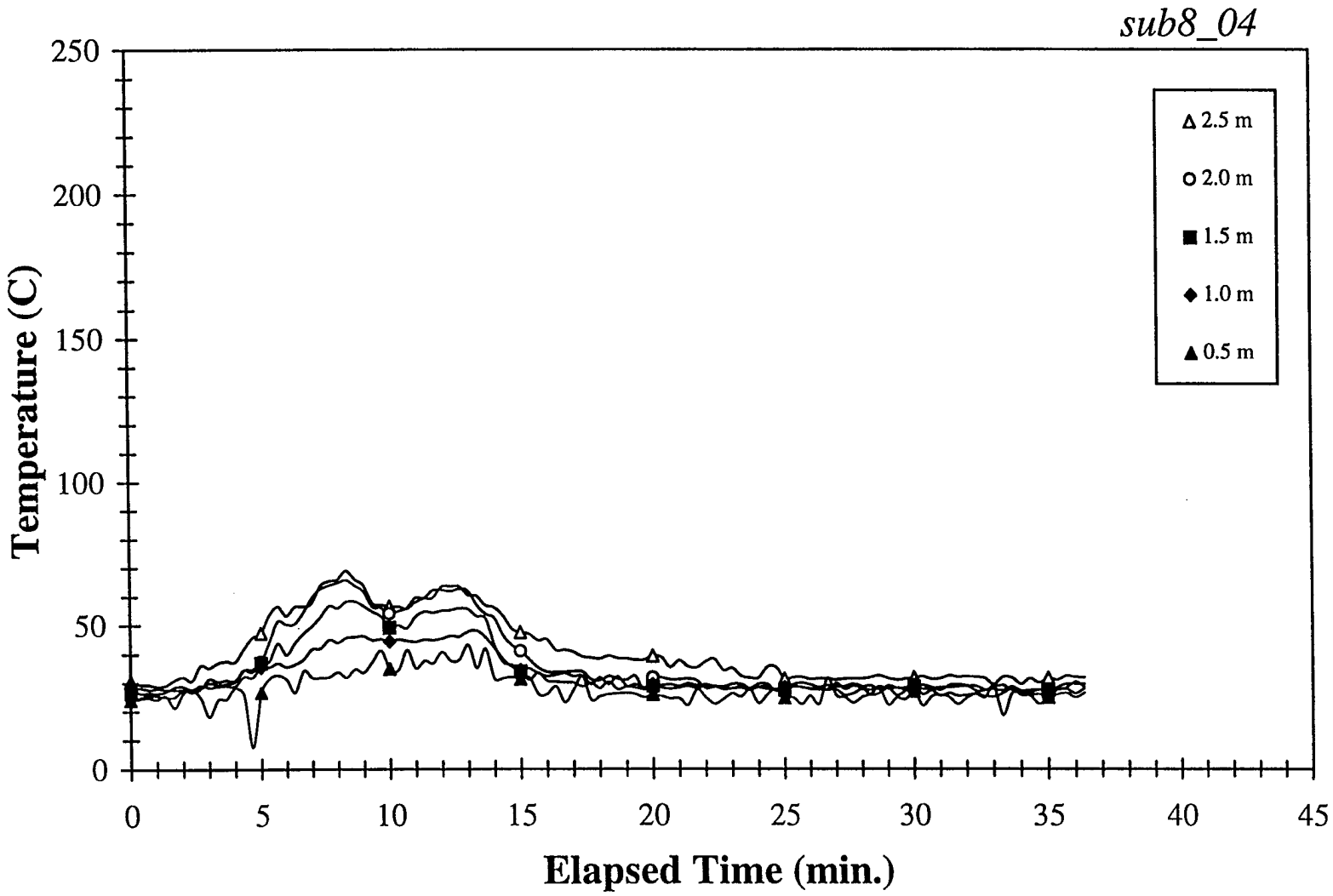

Fig. F11 – Control Room – Forward TC Tree

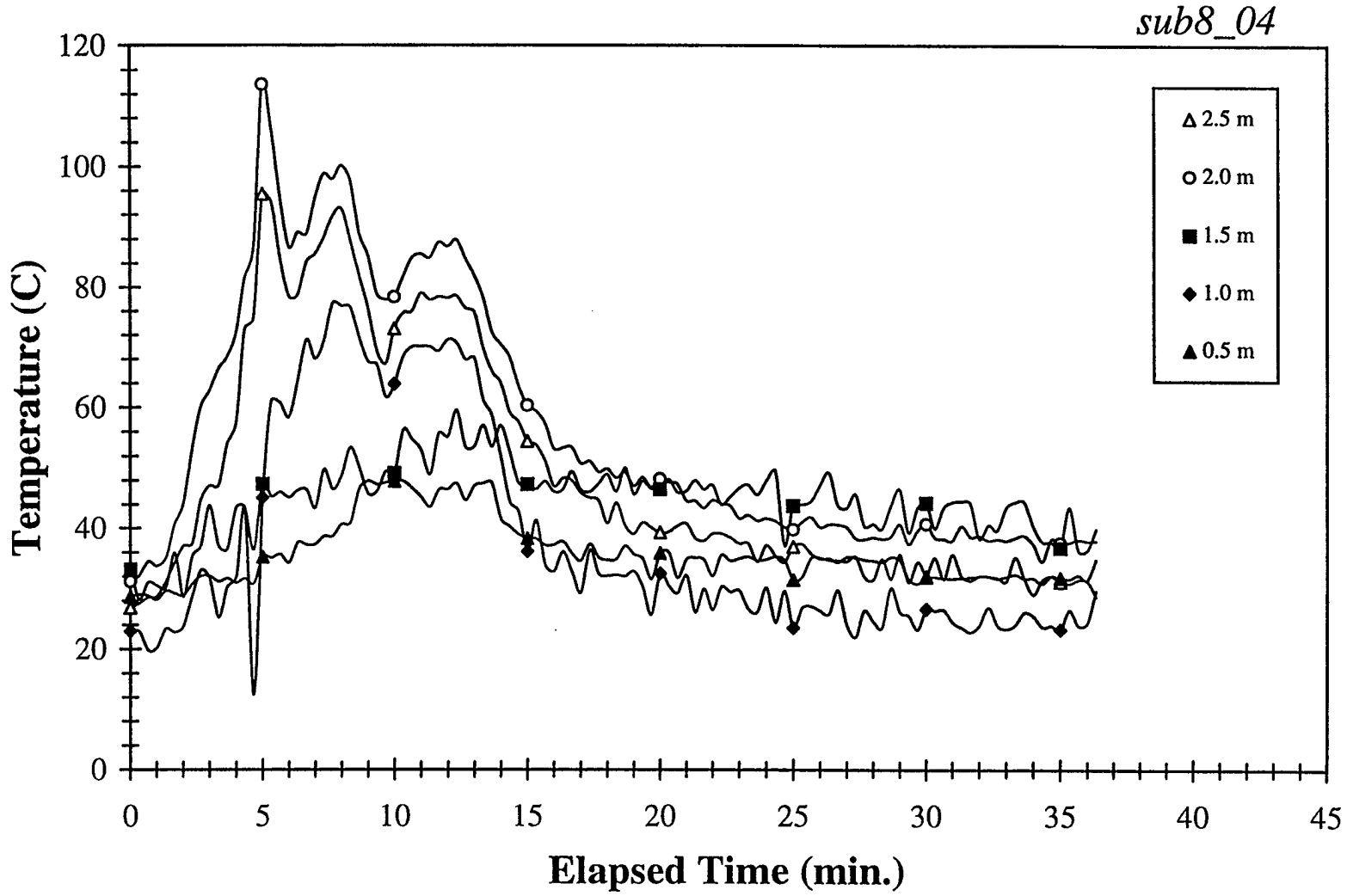

Fig. F12 – Control Room – Aft TC Tree

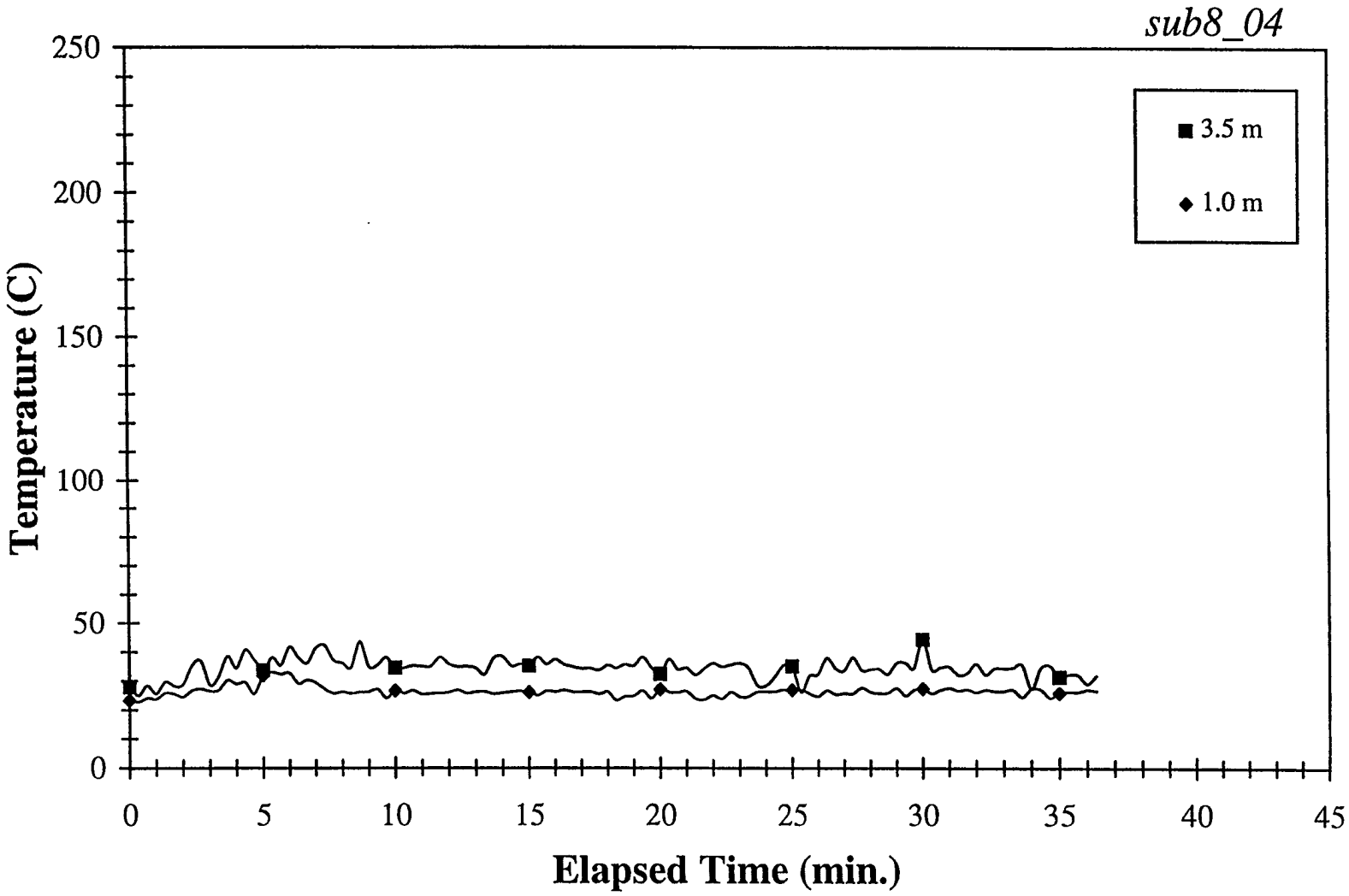

Fig. F13 – Fan Room TC Tree

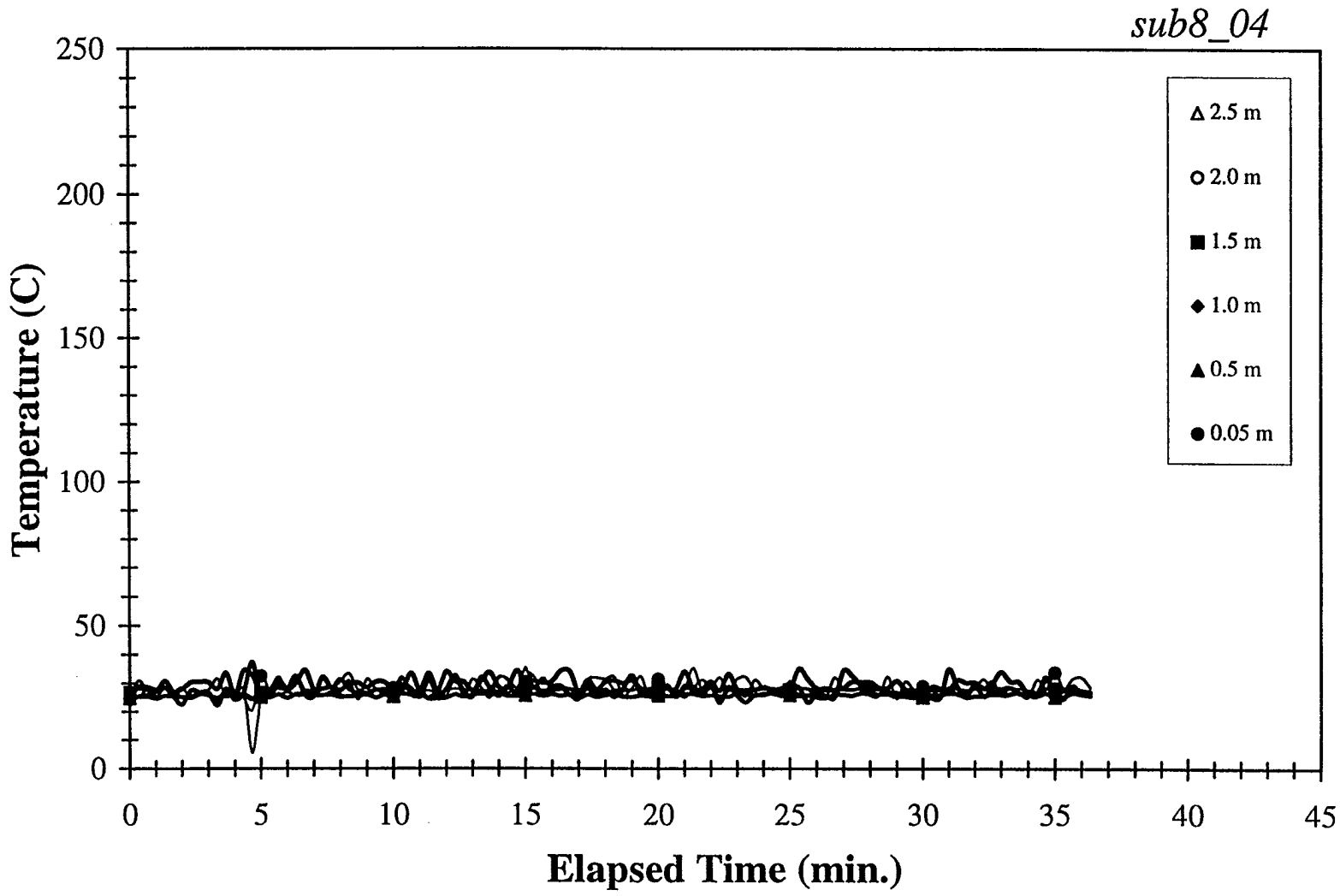

Fig. F14 – Crew Living – Forward TC Tree

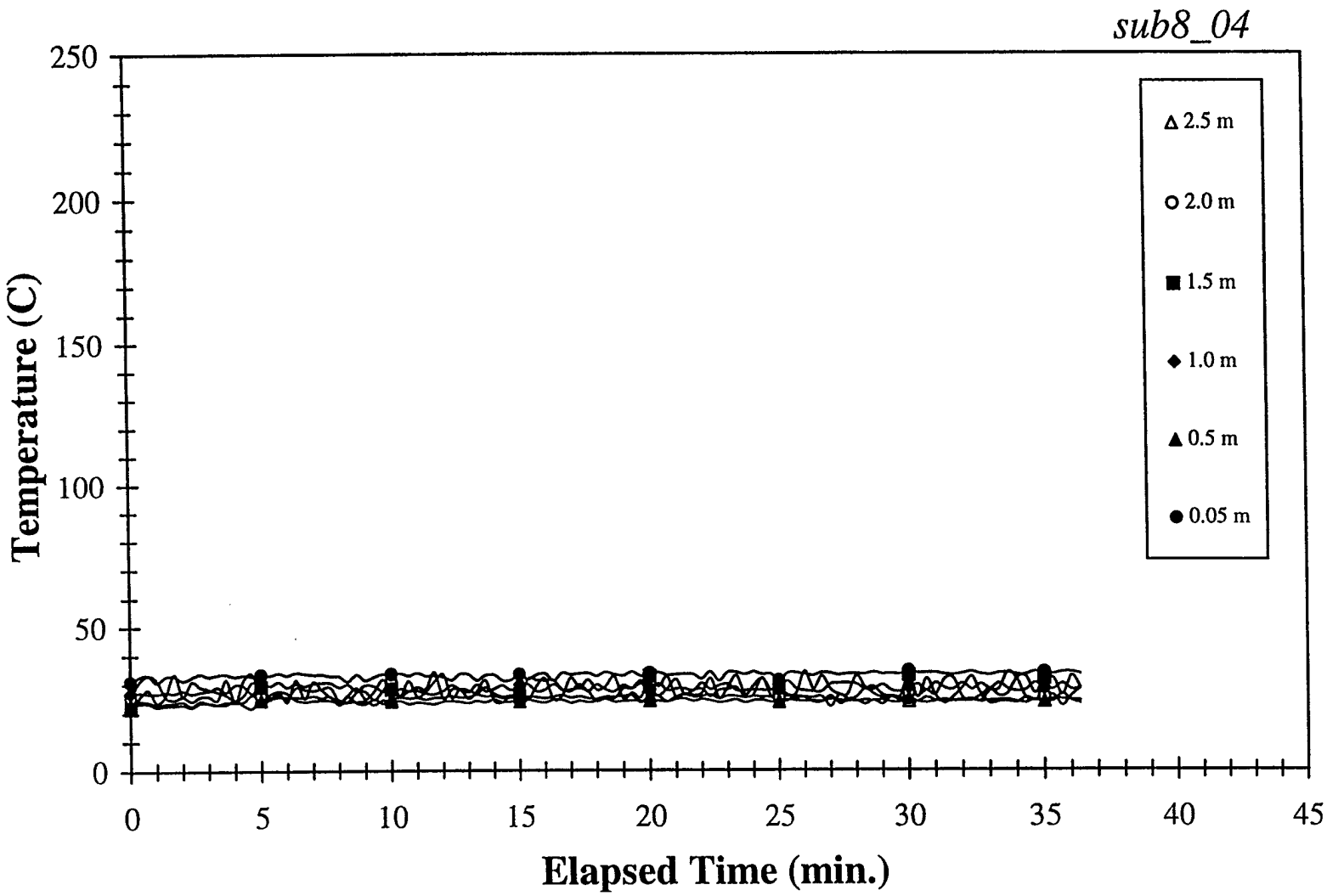

Fig. F15 – Crew Living – Aft TC Tree

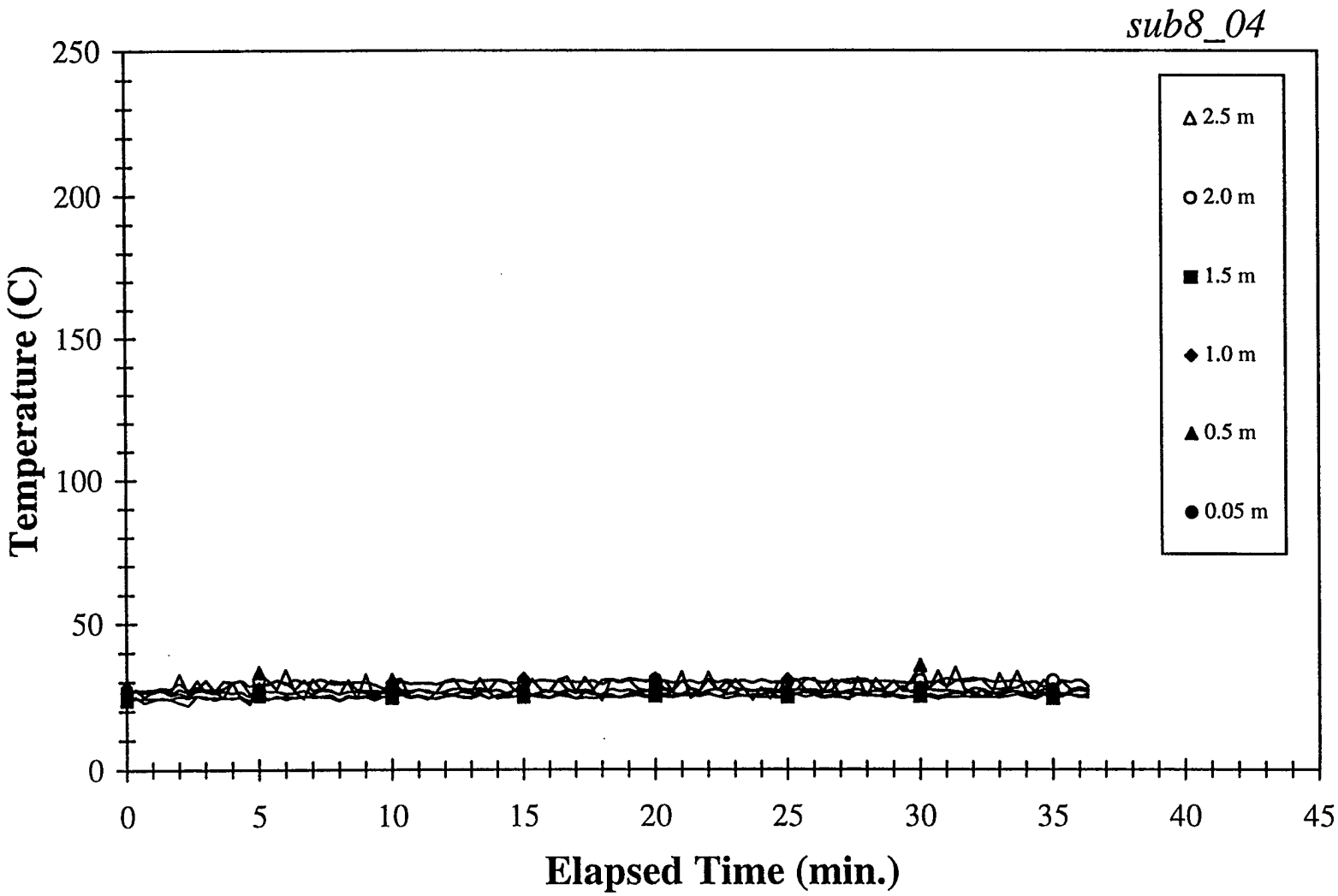

Fig. F16 – Wardroom – Forward TC Tree

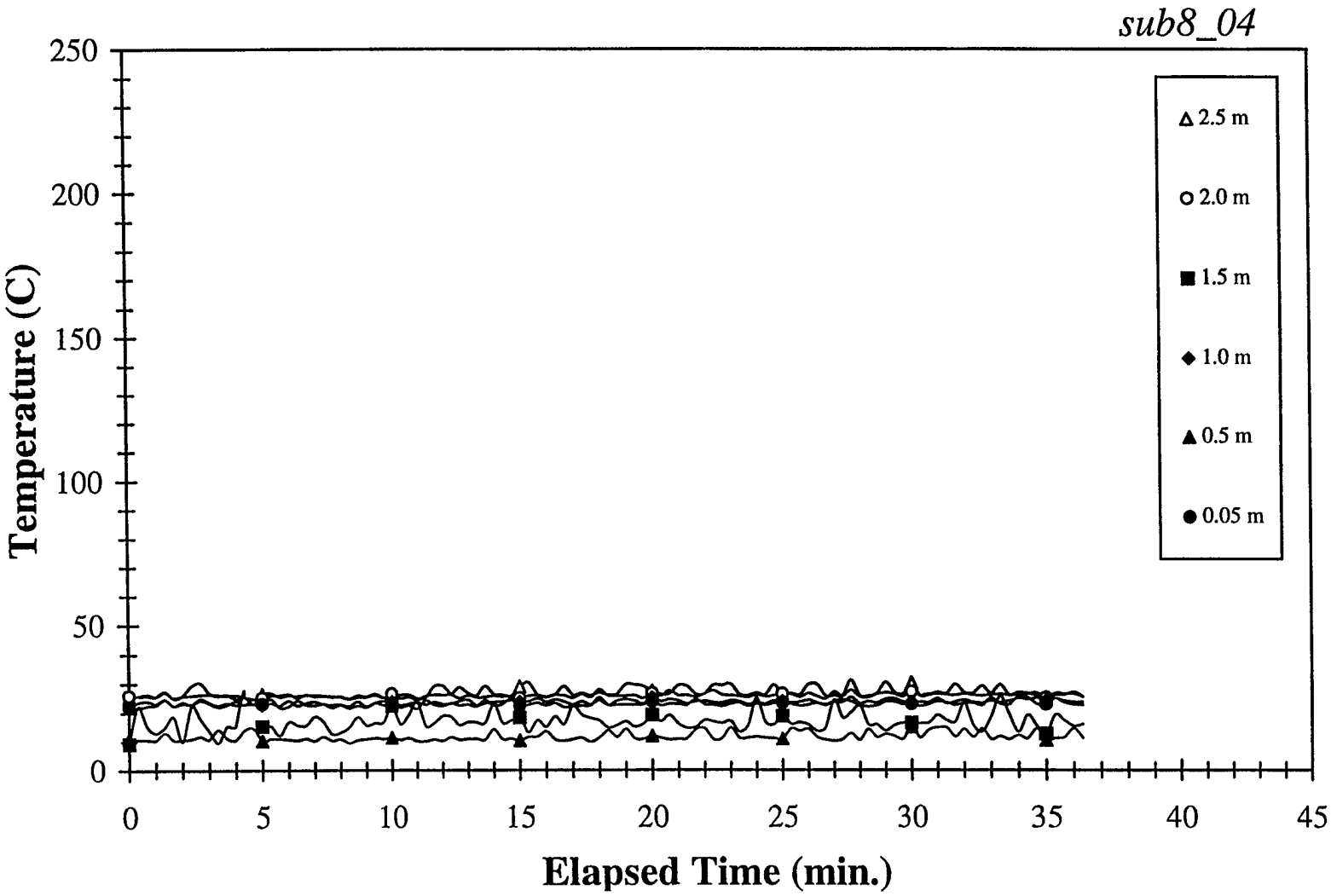

Fig. F17 – Wardroom – Aft TC Tree

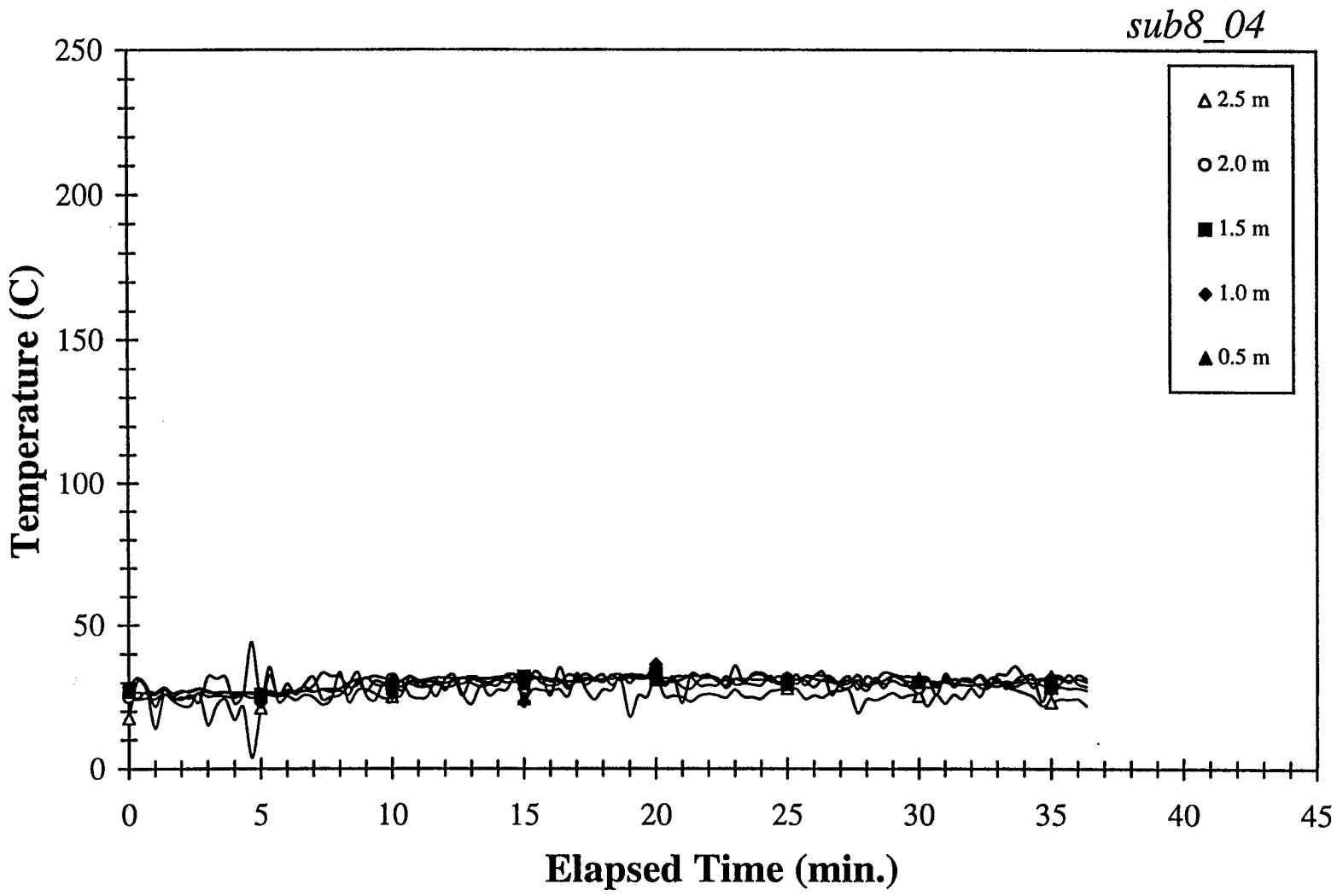

Fig. F18 – CPO/Crew Mess – Forward TC Tree

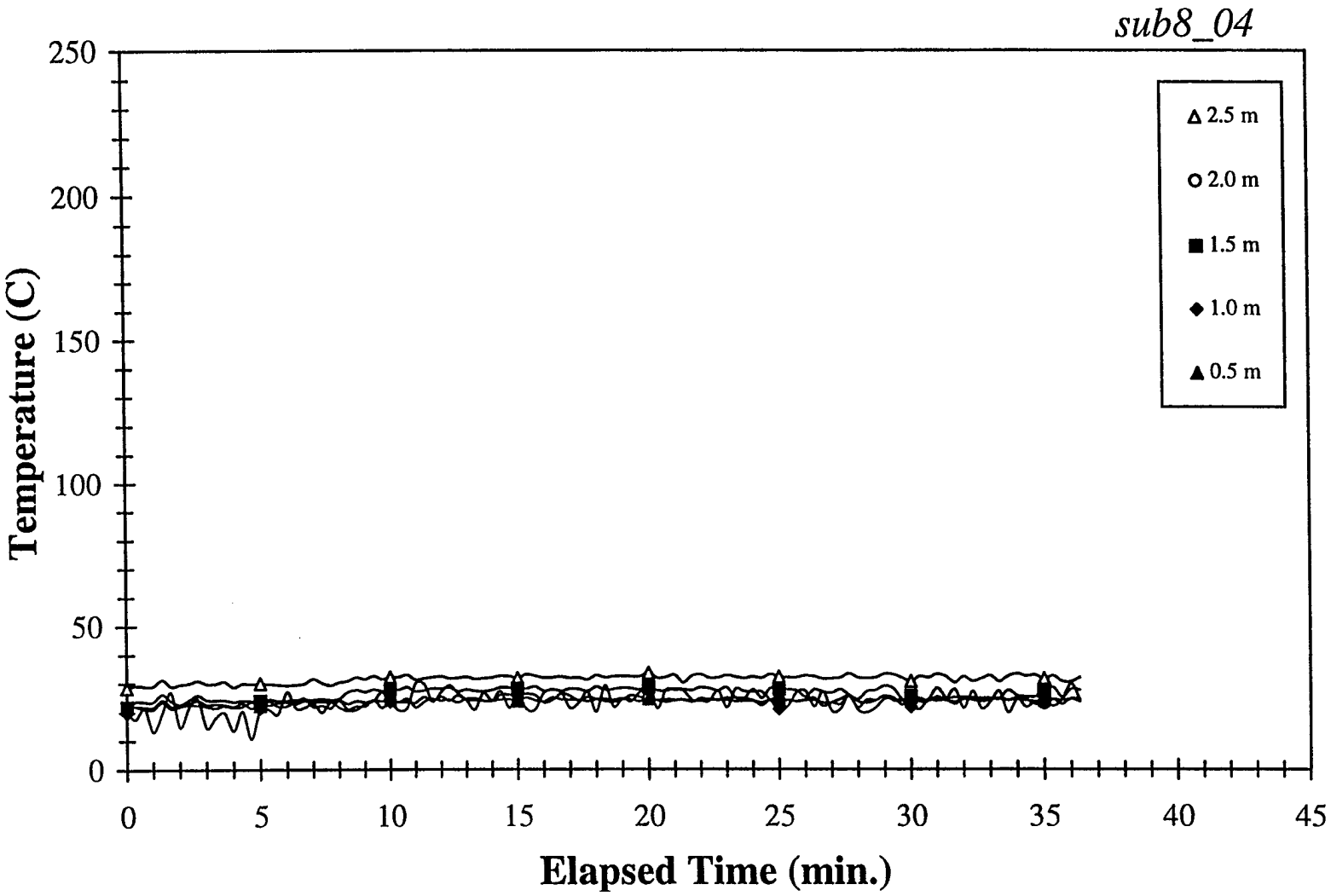

Fig. F19 – CPO/Crew Mess – Aft TC Tree

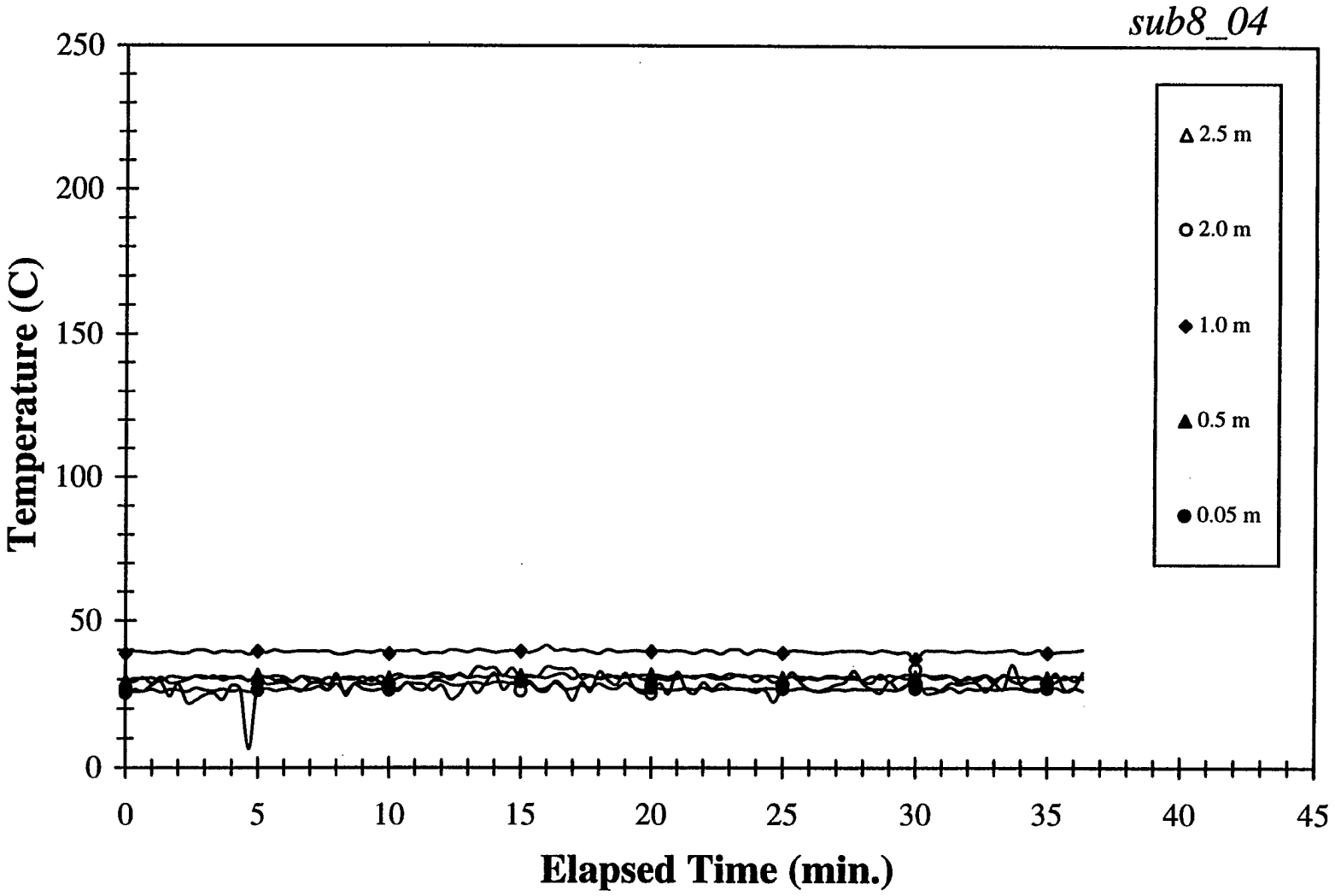

Fig. F20 – Torpedo Room – Forward TC Tree

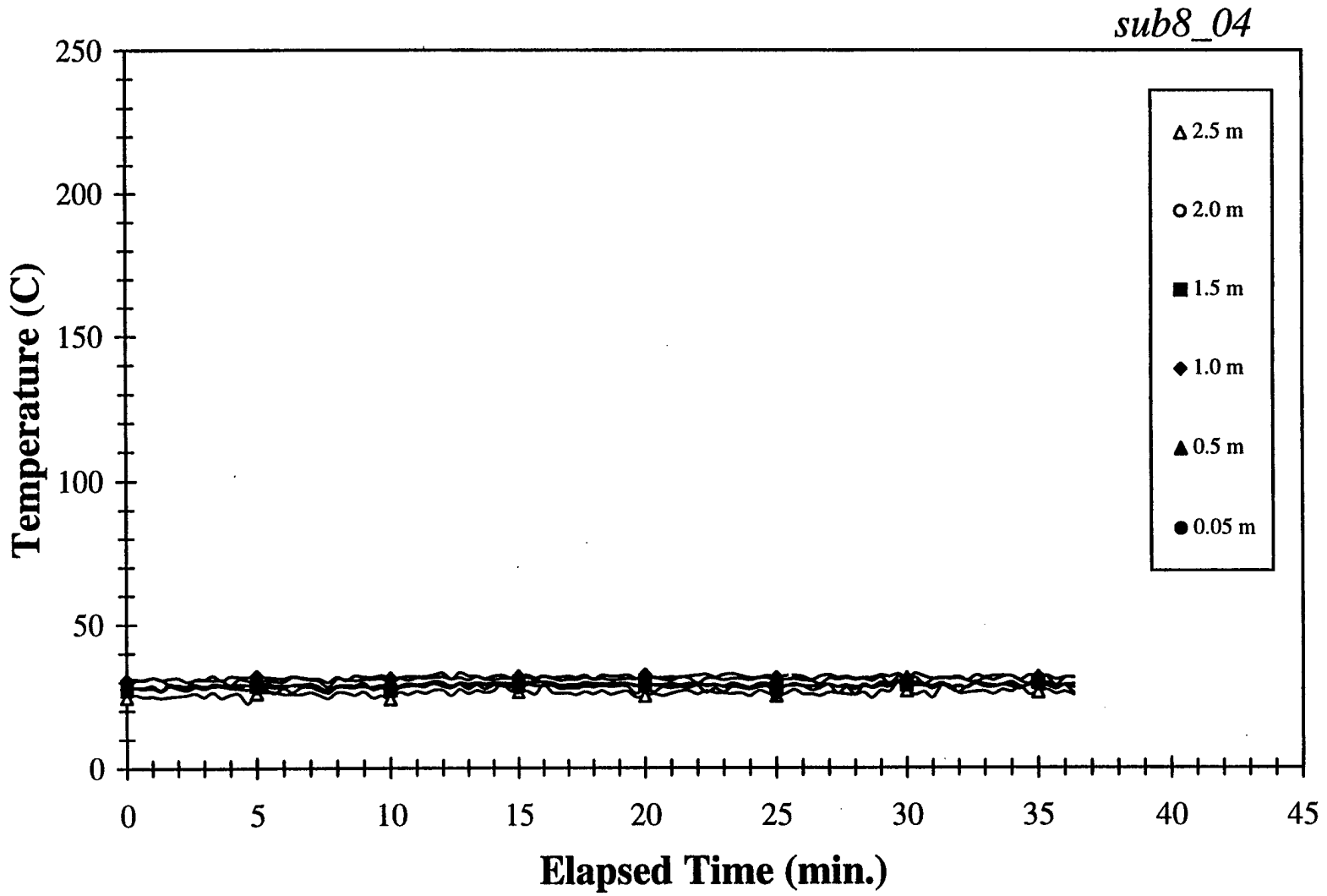

Fig. F21 – Torpedo Room – Aft TC Tree

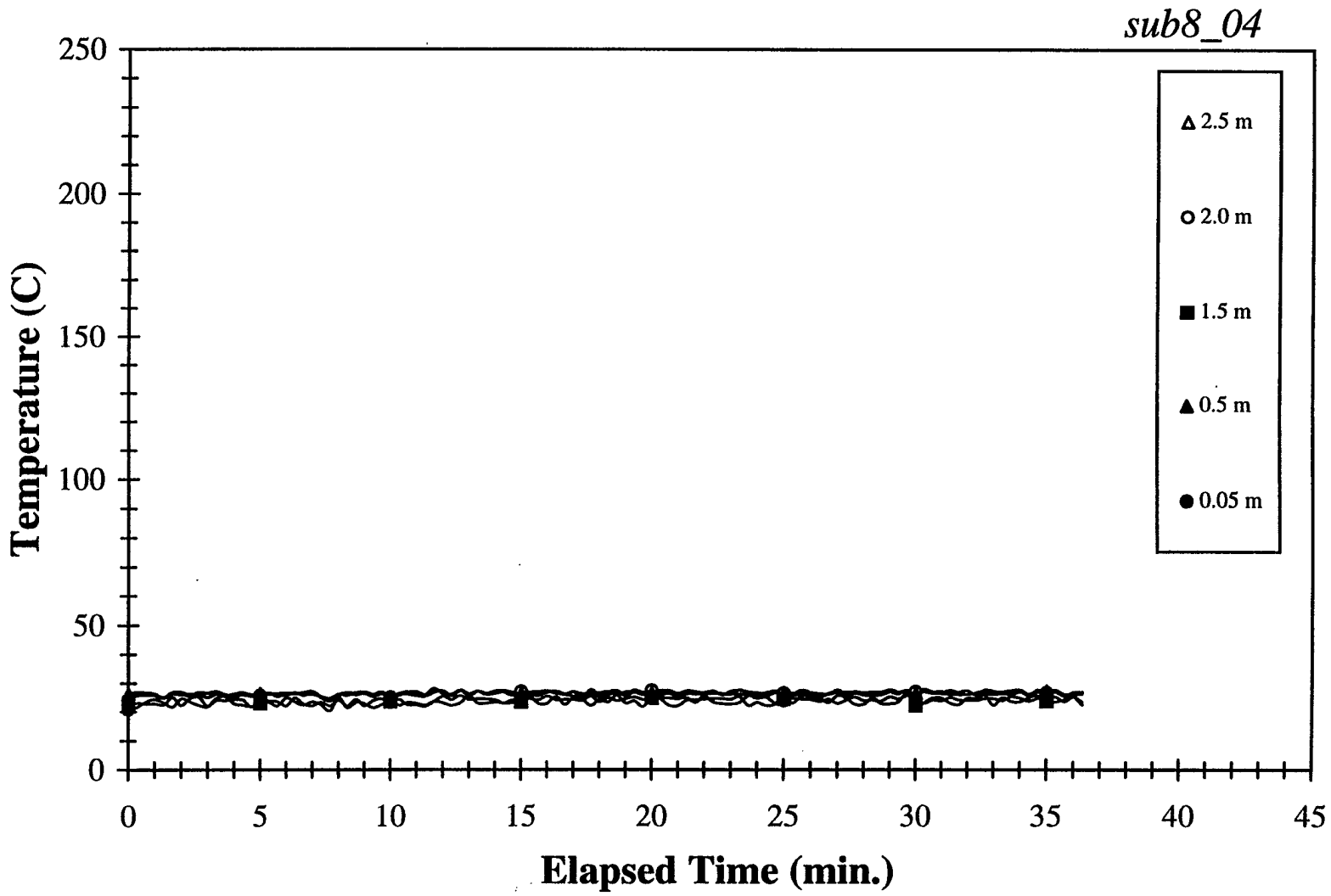

Fig. F22 – Laundry – Forward TC Tree

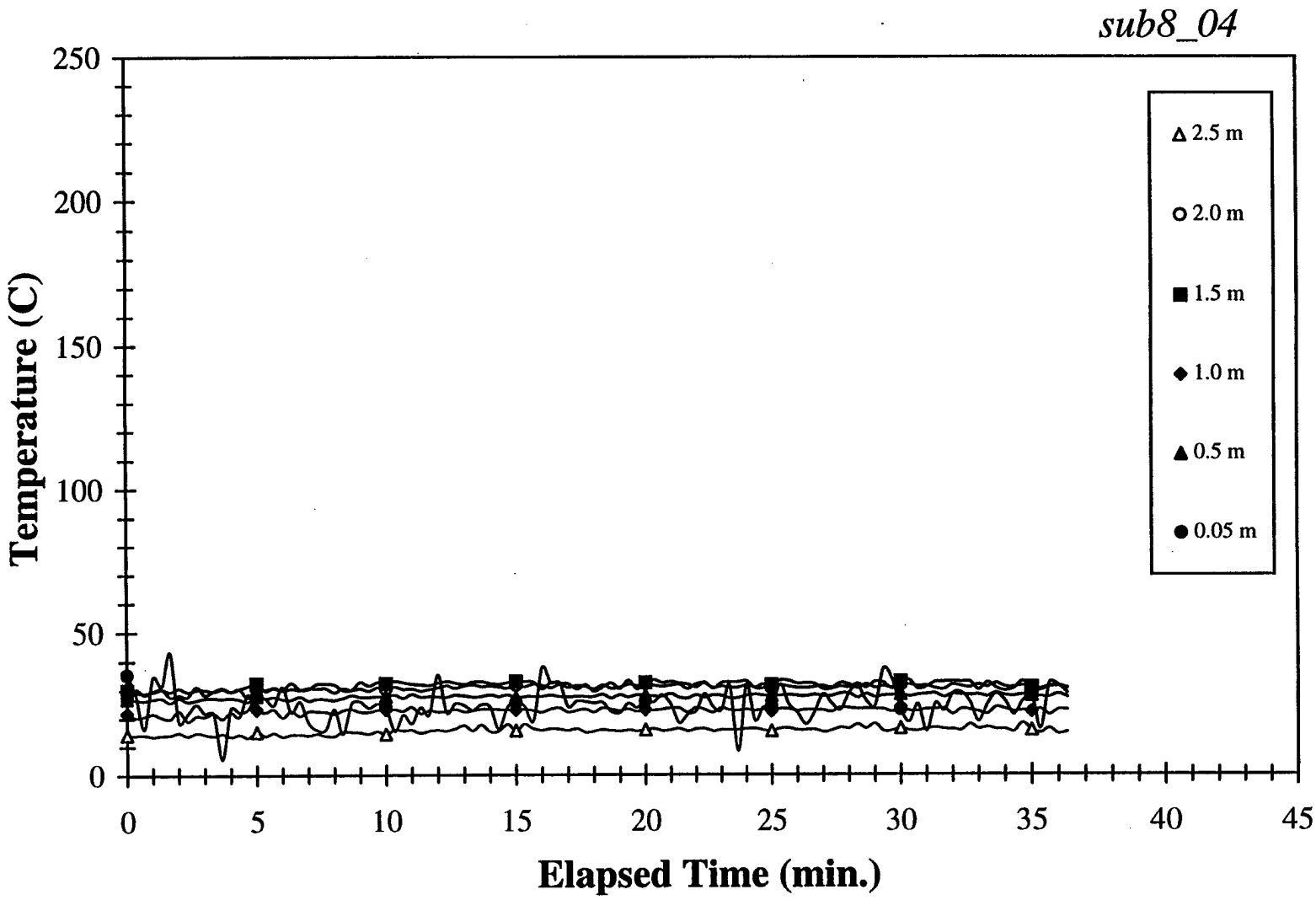

Fig. F23 - Laundry - Aft TC Tree

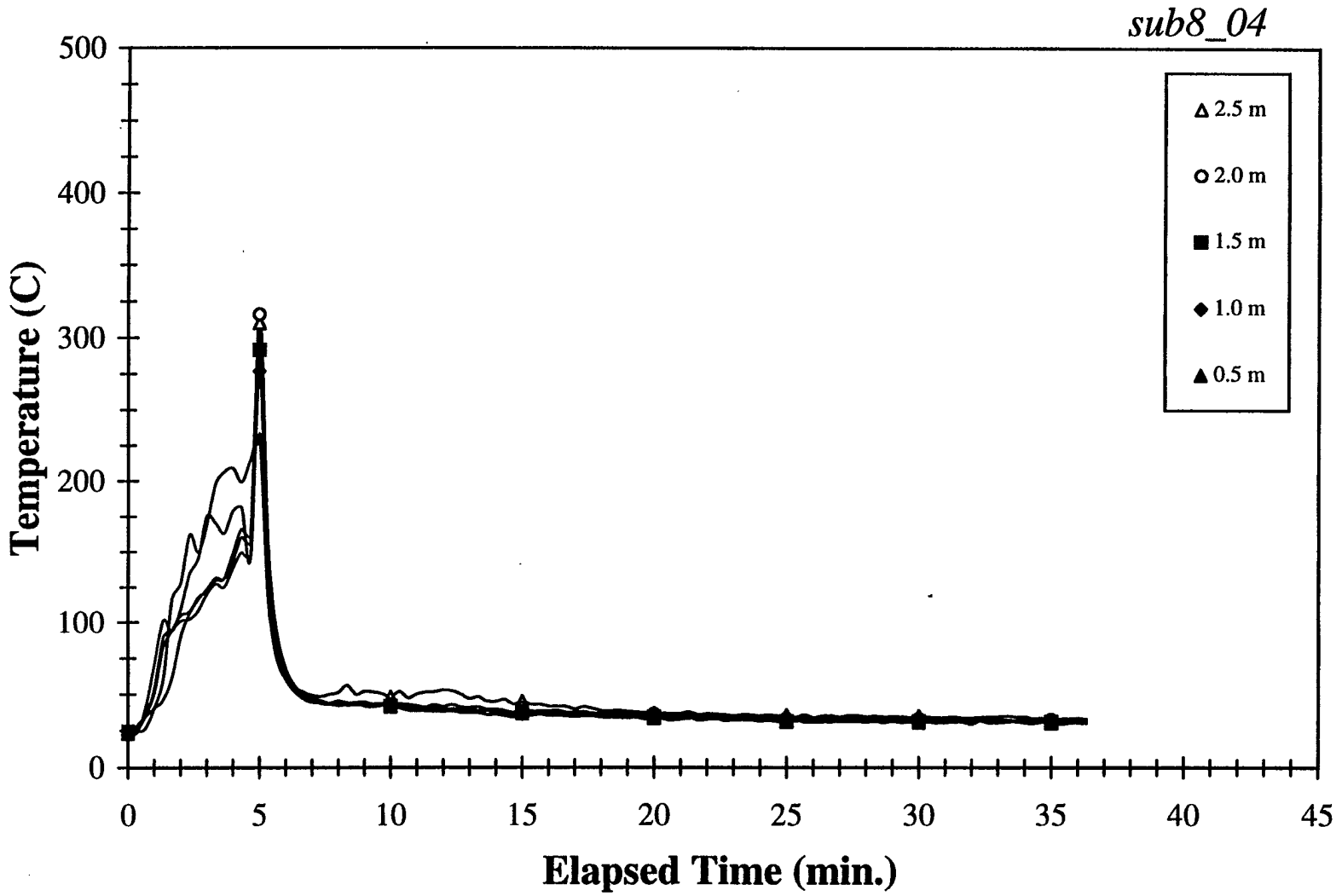

Fig. F24 – AMR – Forward TC Tree

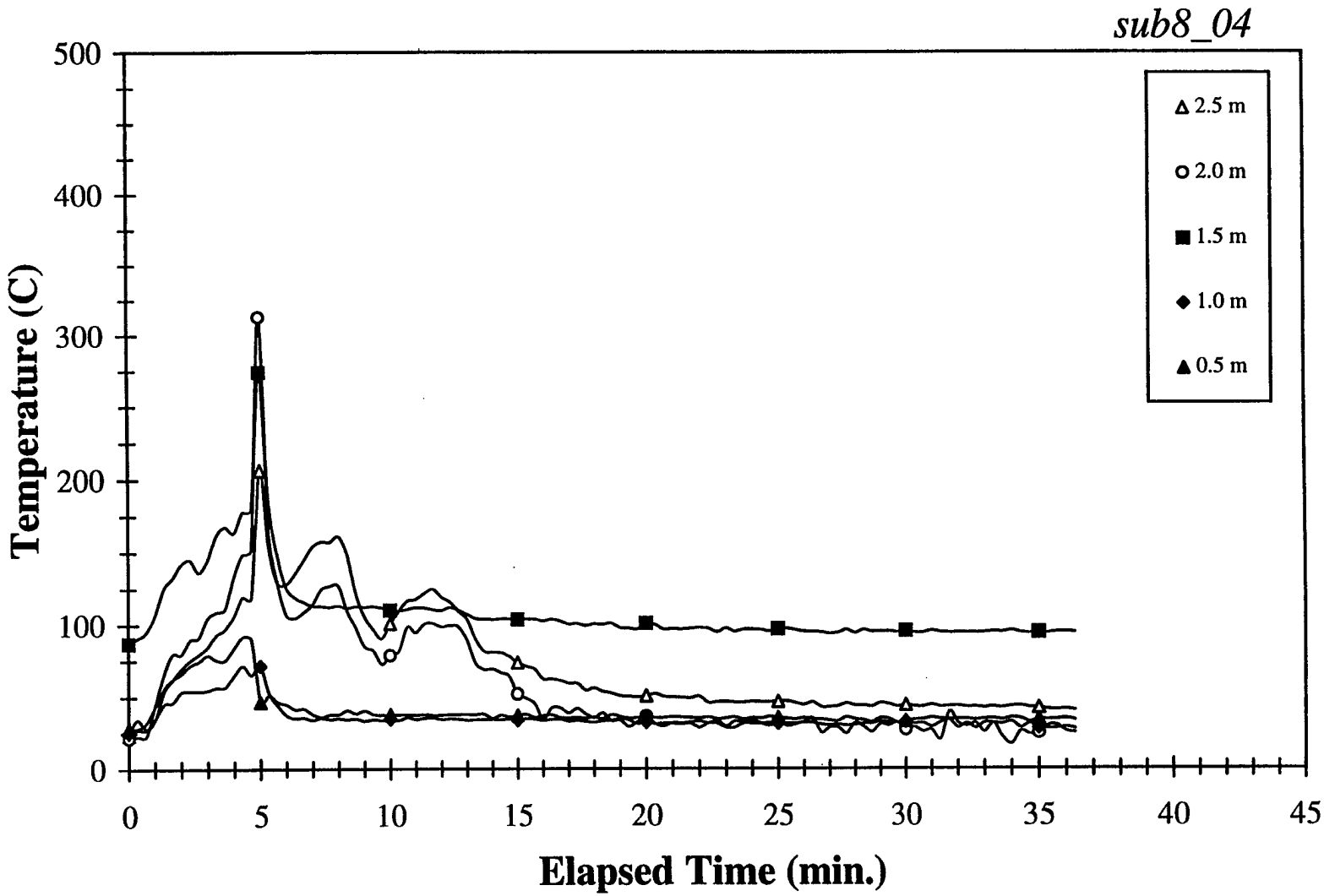

Fig. F25 – AMR – Forward TC Tree

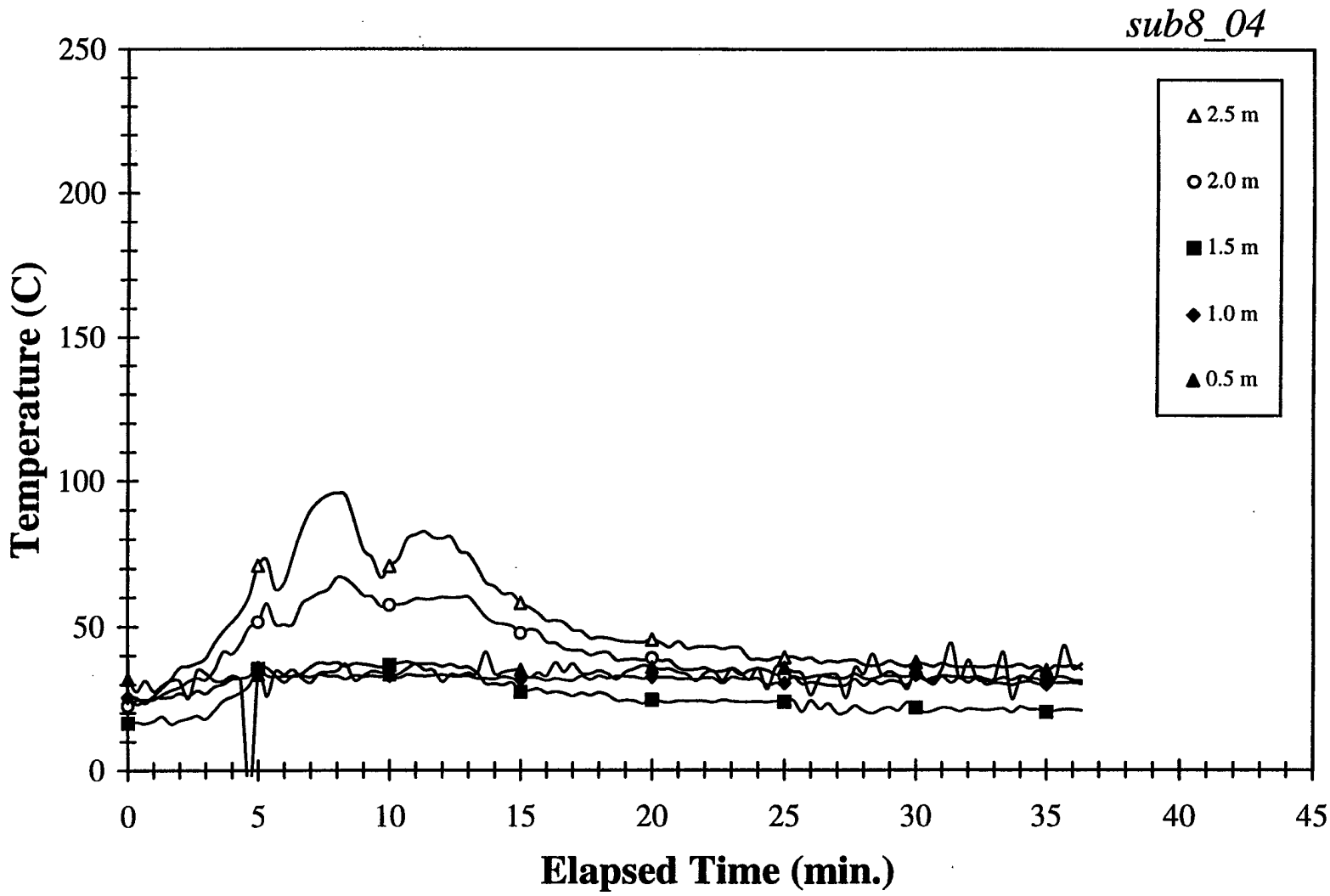

Fig. F26 – AMR – Aft TC Tree

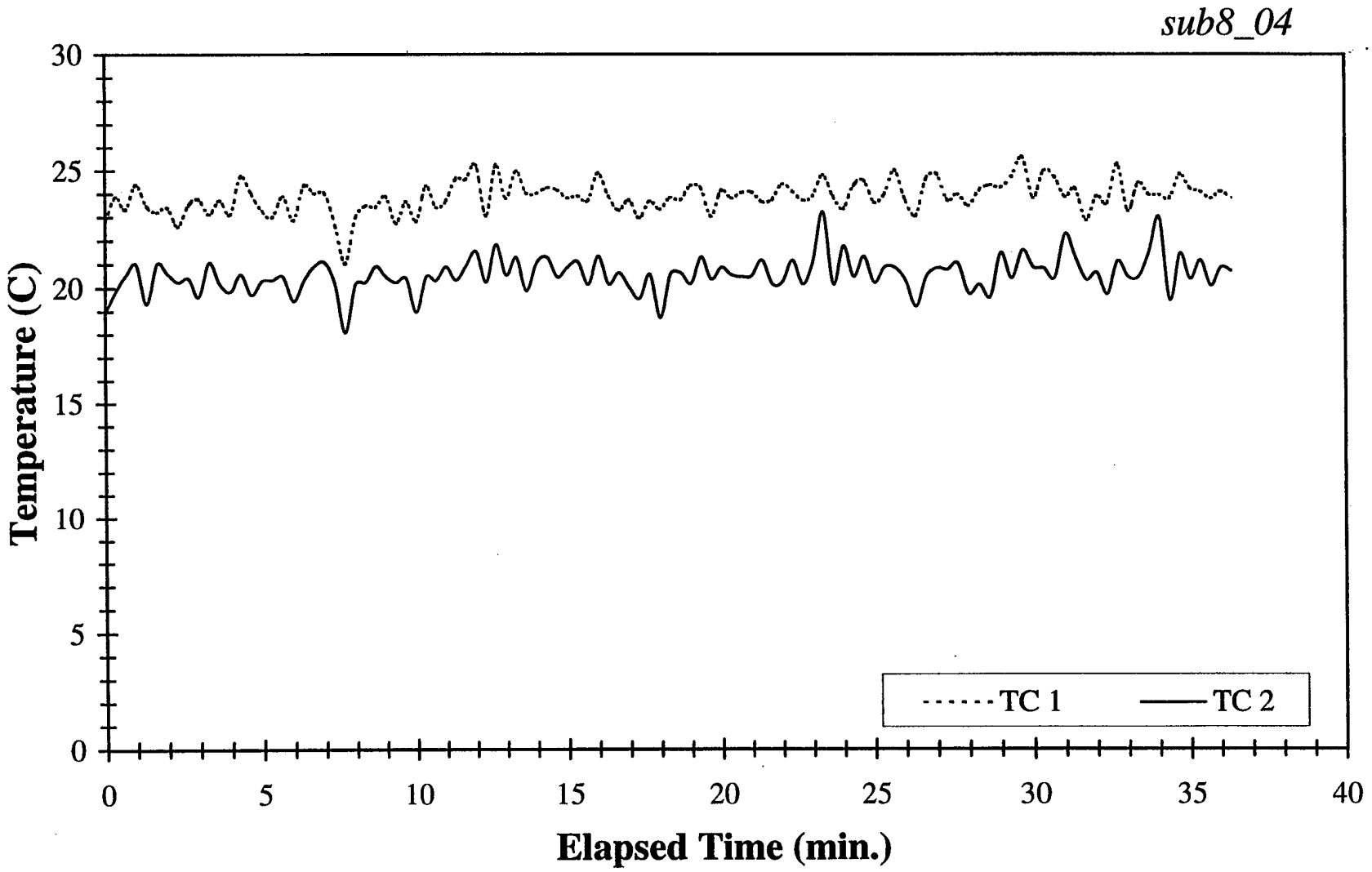

Fig. F27 – Laundry fire temperatures

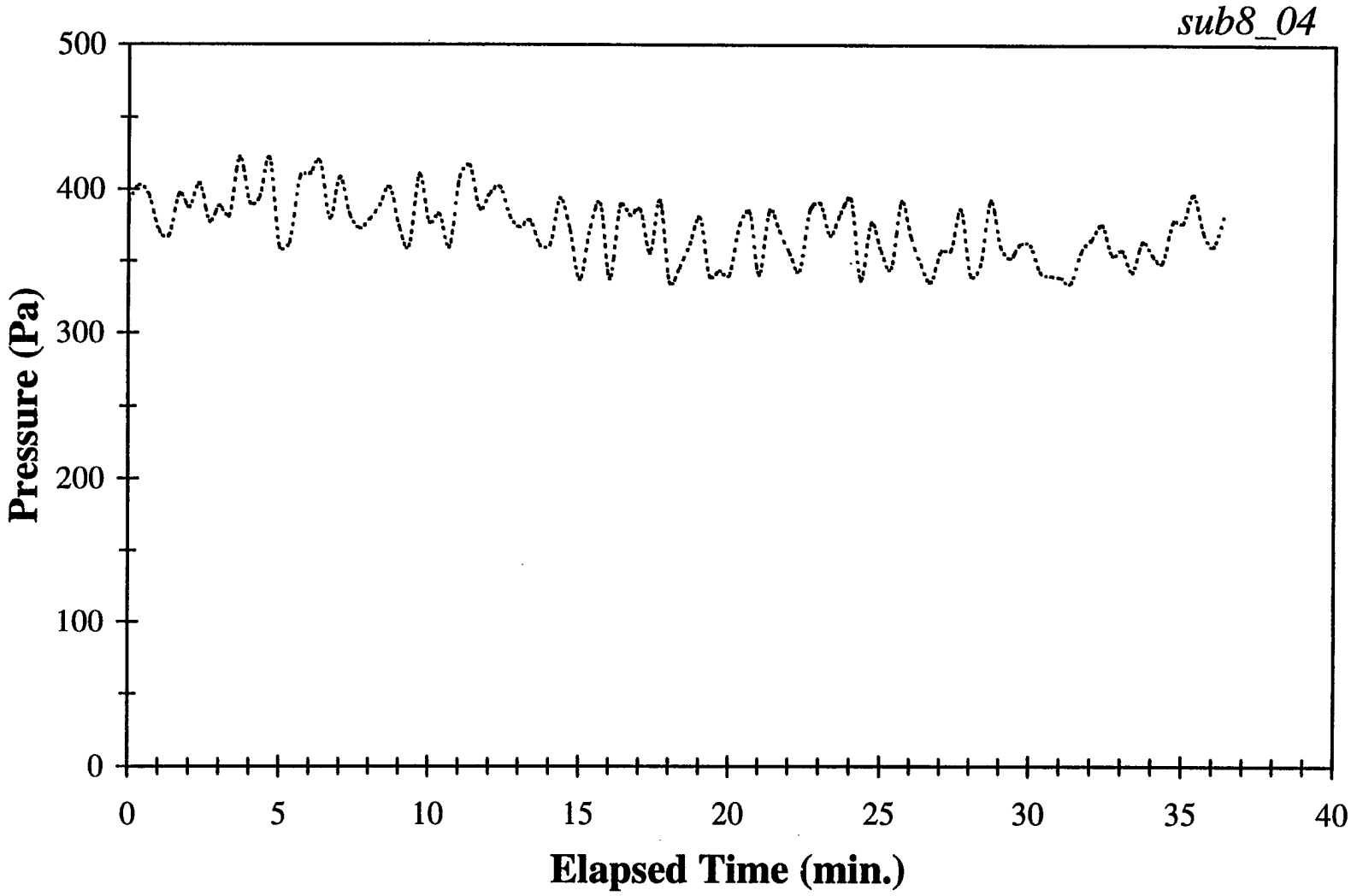

Fig. F28 – Combat Systems pressure @ 2.5–m height

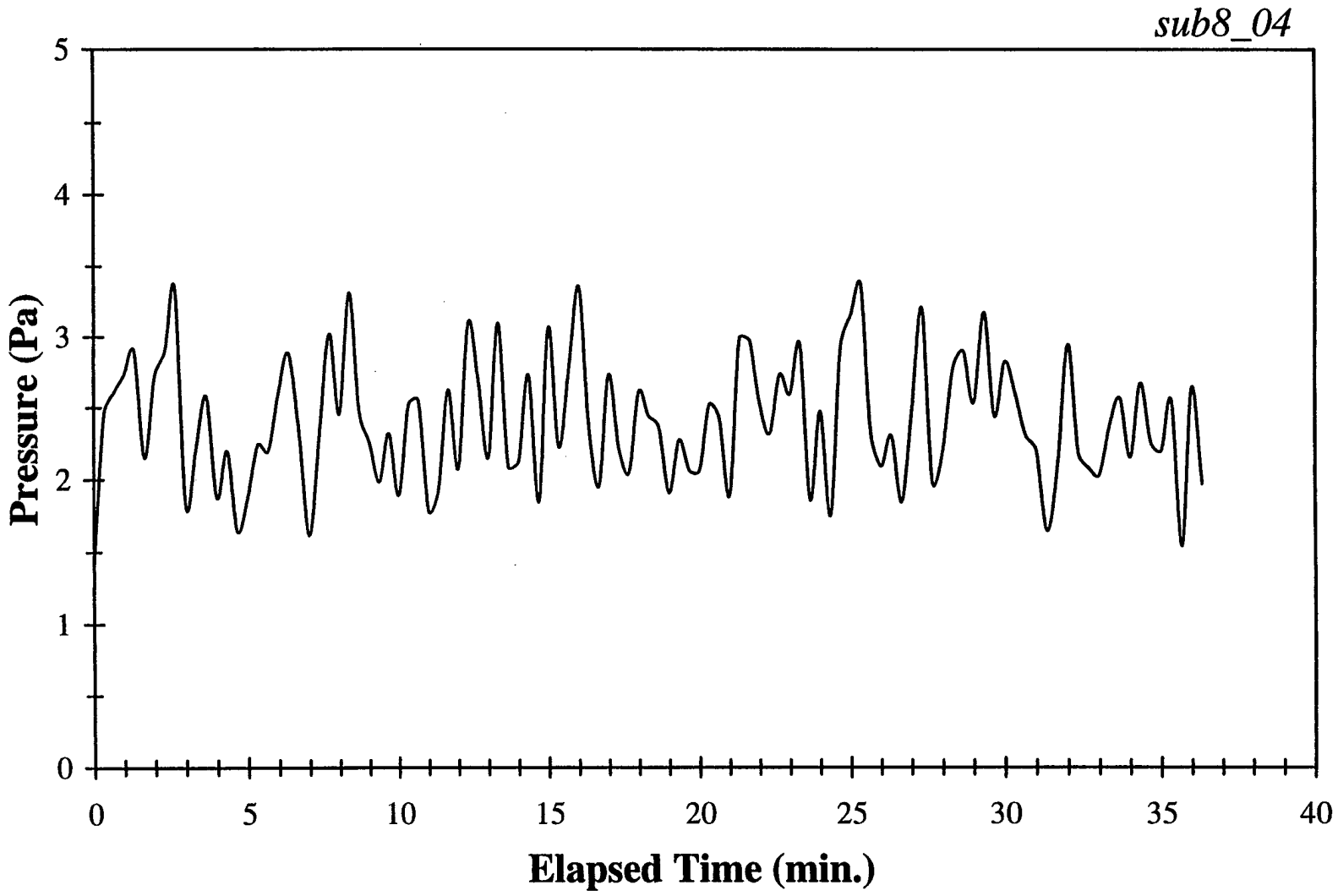

Fig. F29 – Combat Systems pressue @ 1.0–m height

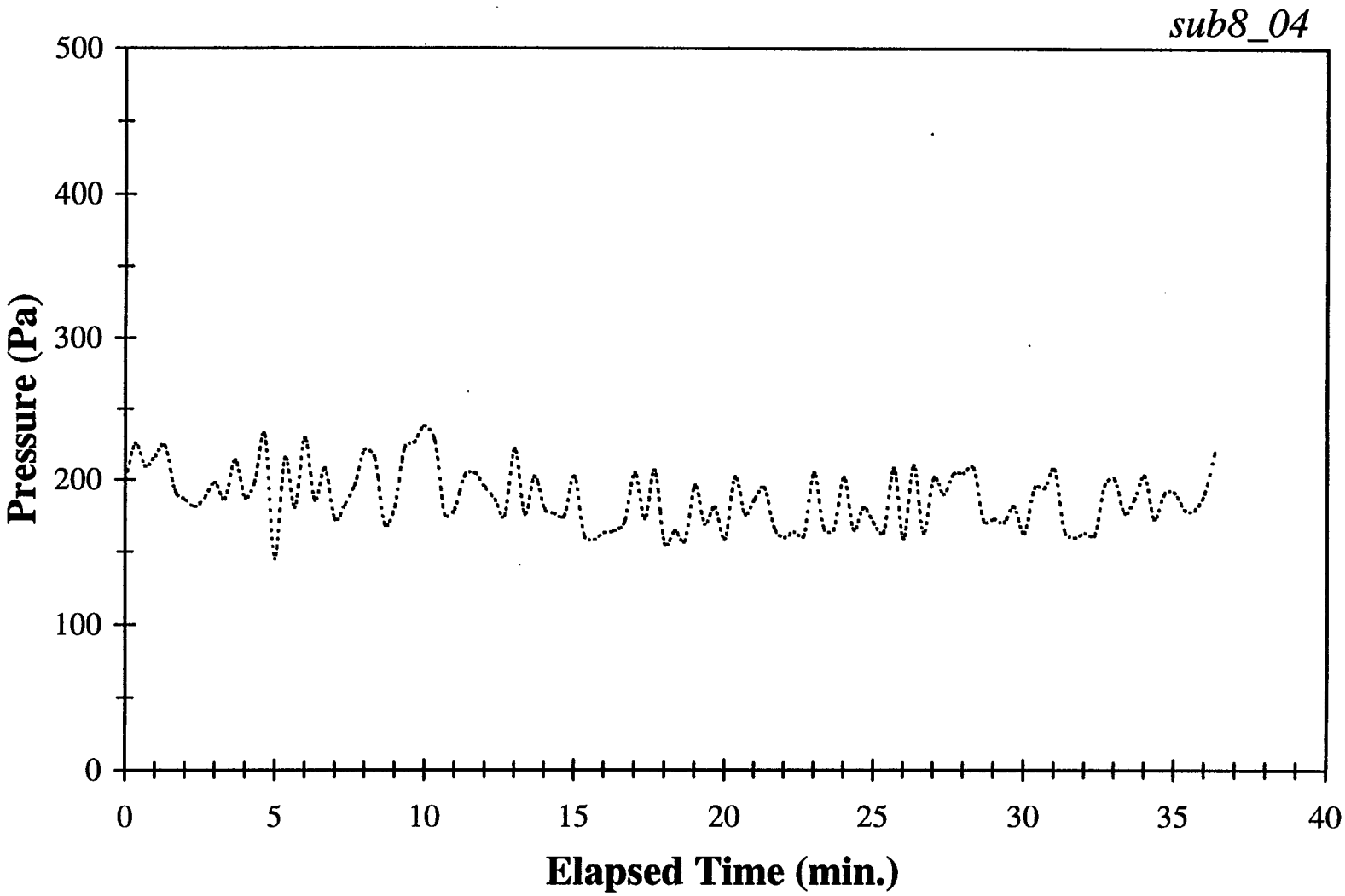

Fig. F30 – Control Room pressure @ 2.5–m height

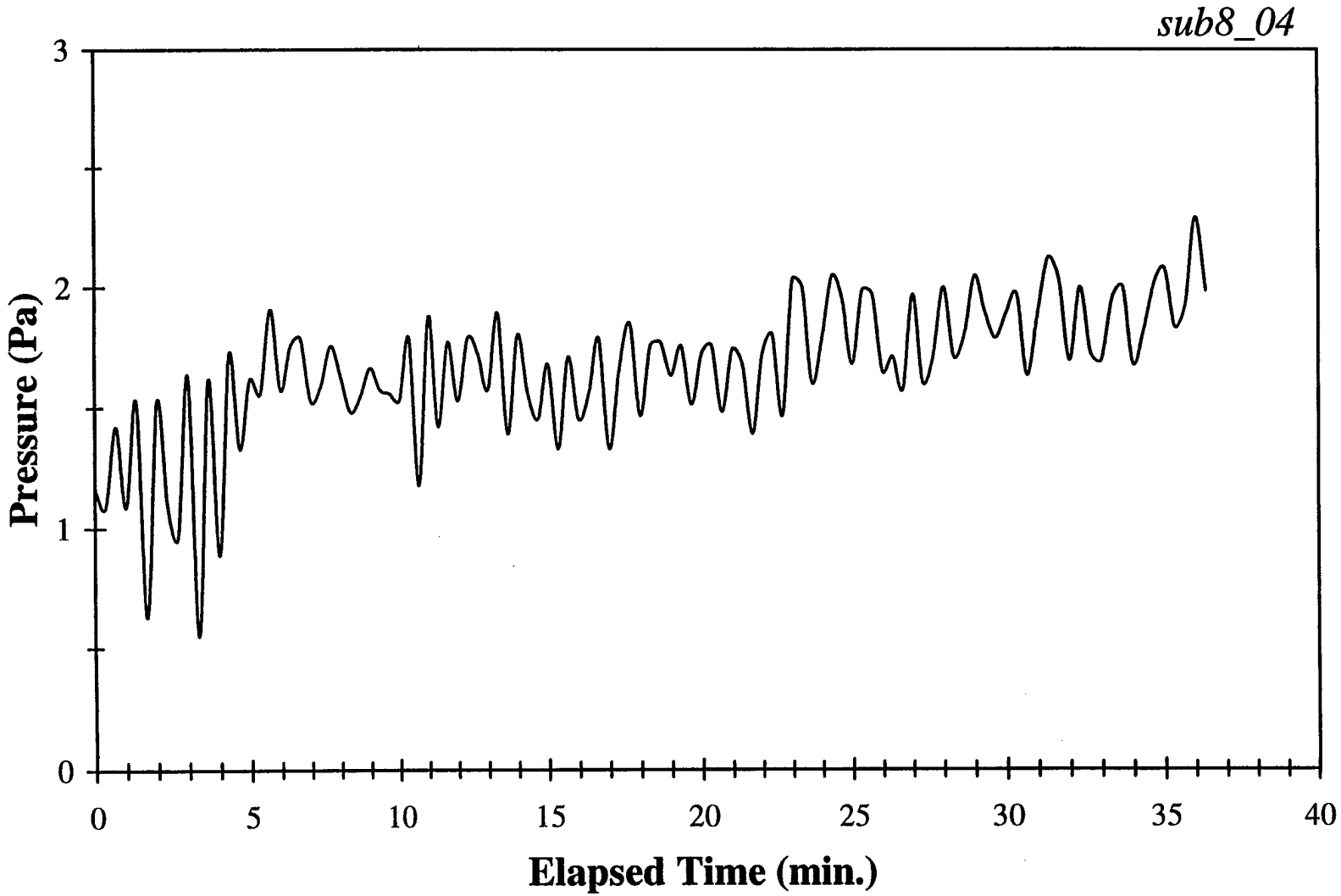

Fig. F31 – Control Room pressure @ 1.0–m height

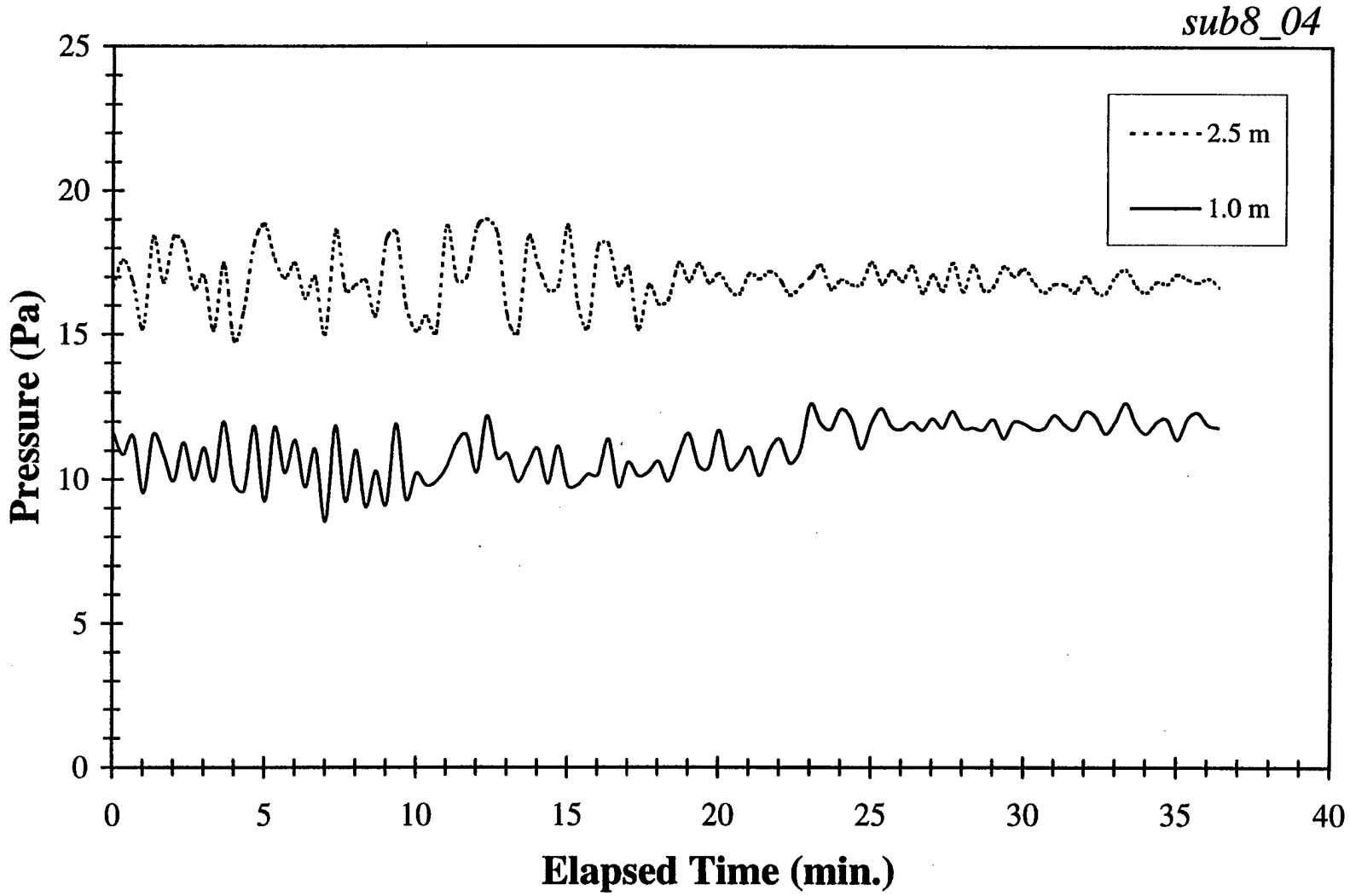

Fig. F32 – Crew Living pressure

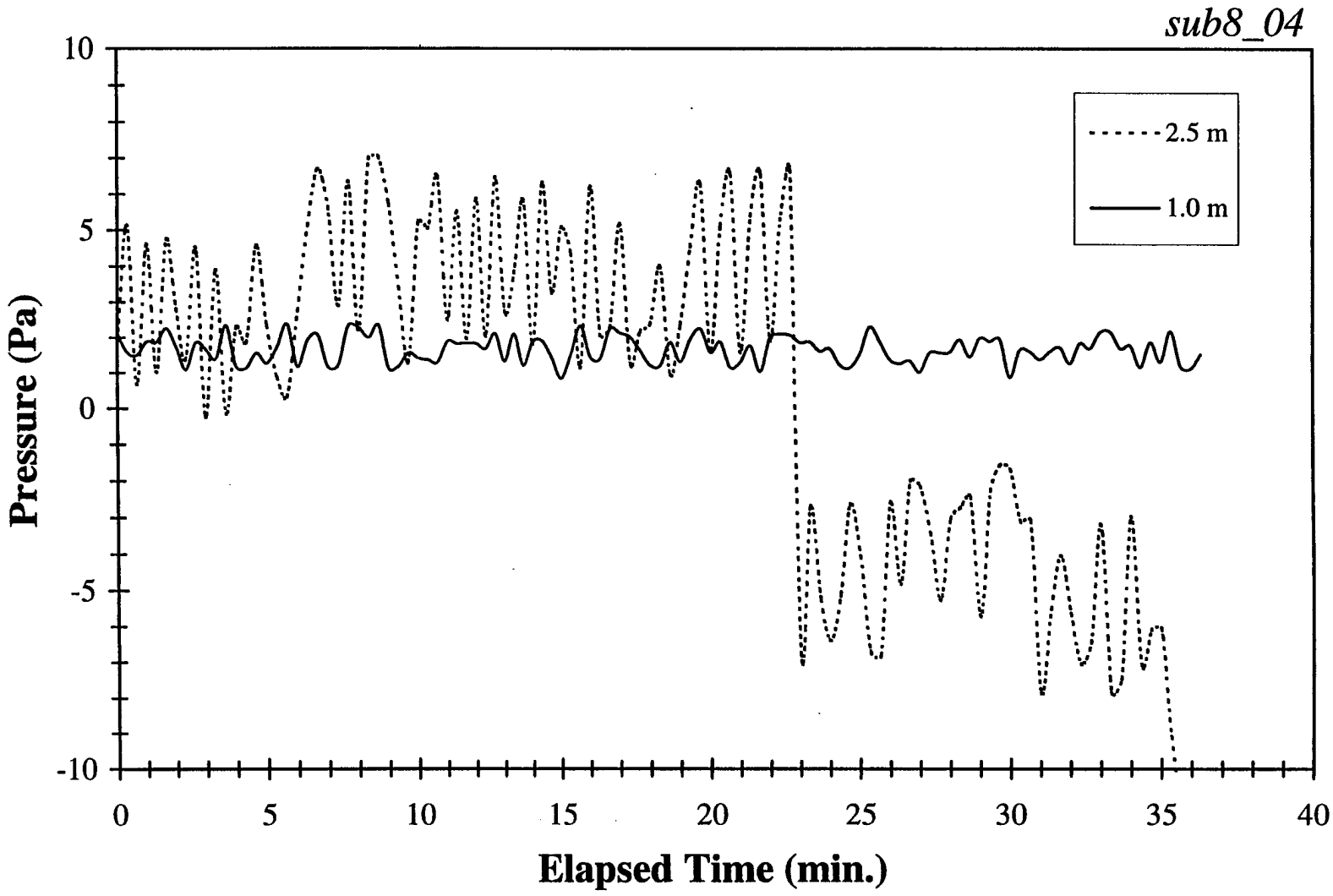

Fig. F33 – Wardroom pressure

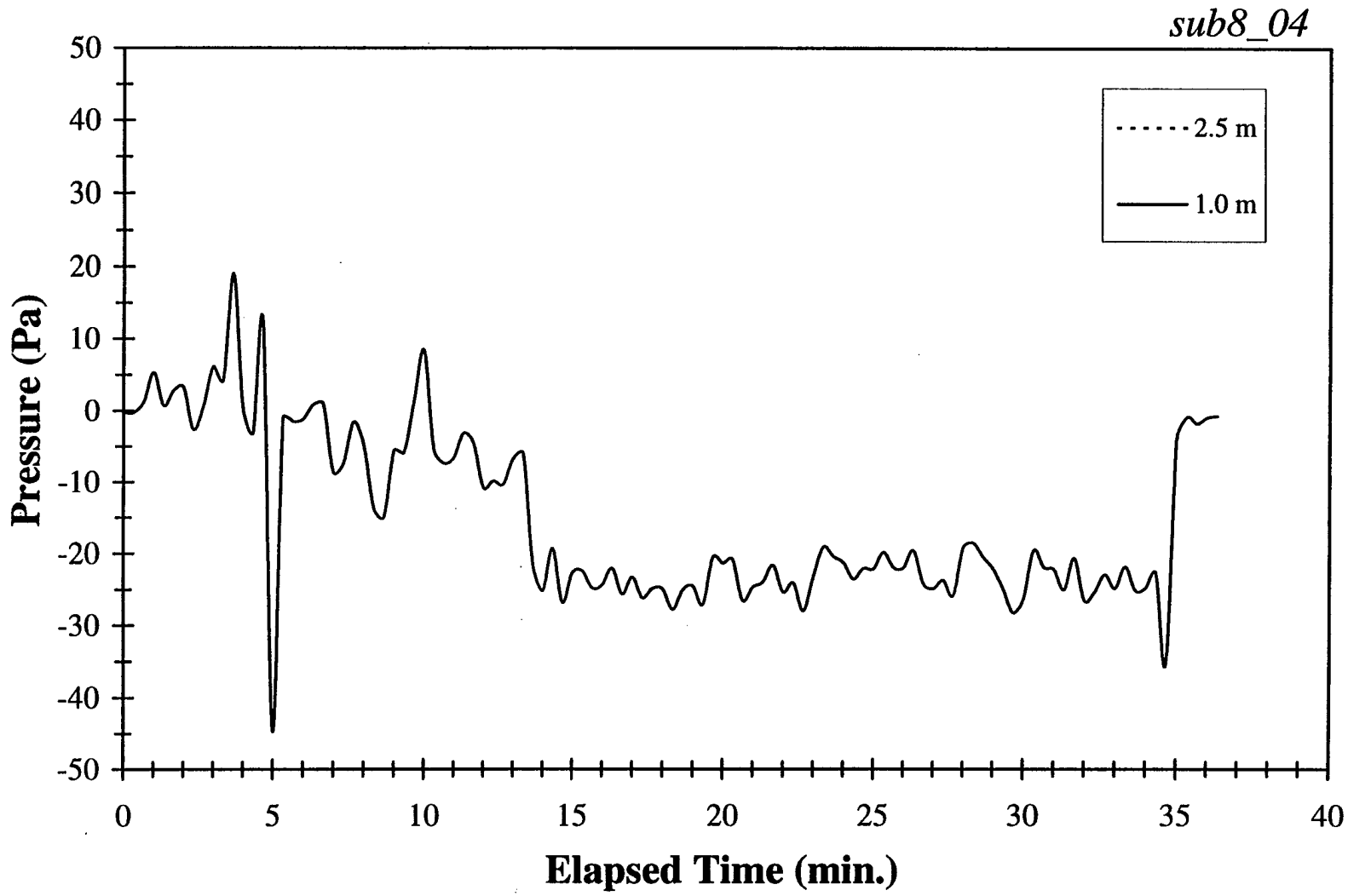

Fig. F34 – Laundry pressure

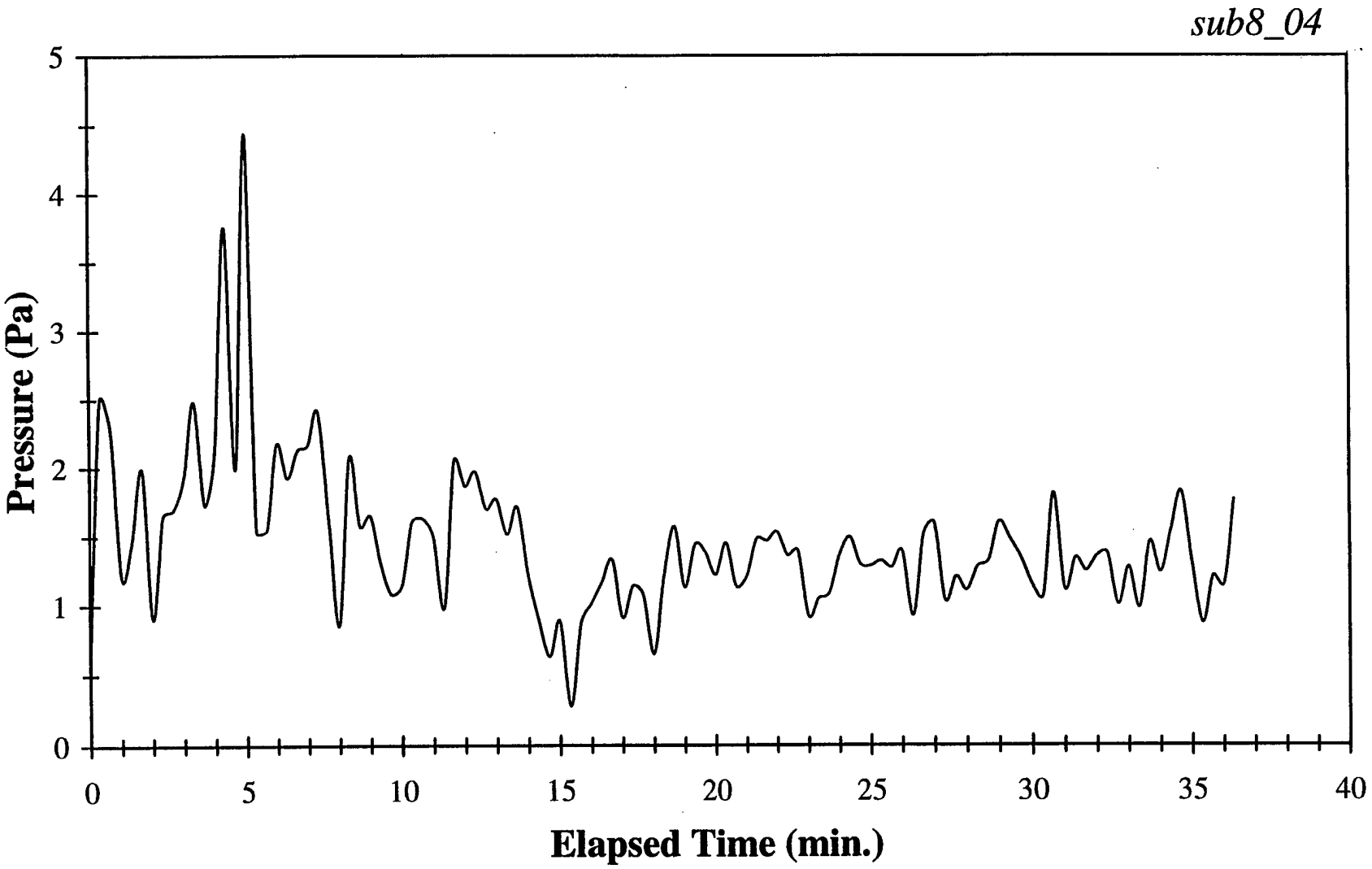

Fig. F35 – Differential pressure (high – Control Room, low – Combat Systems)

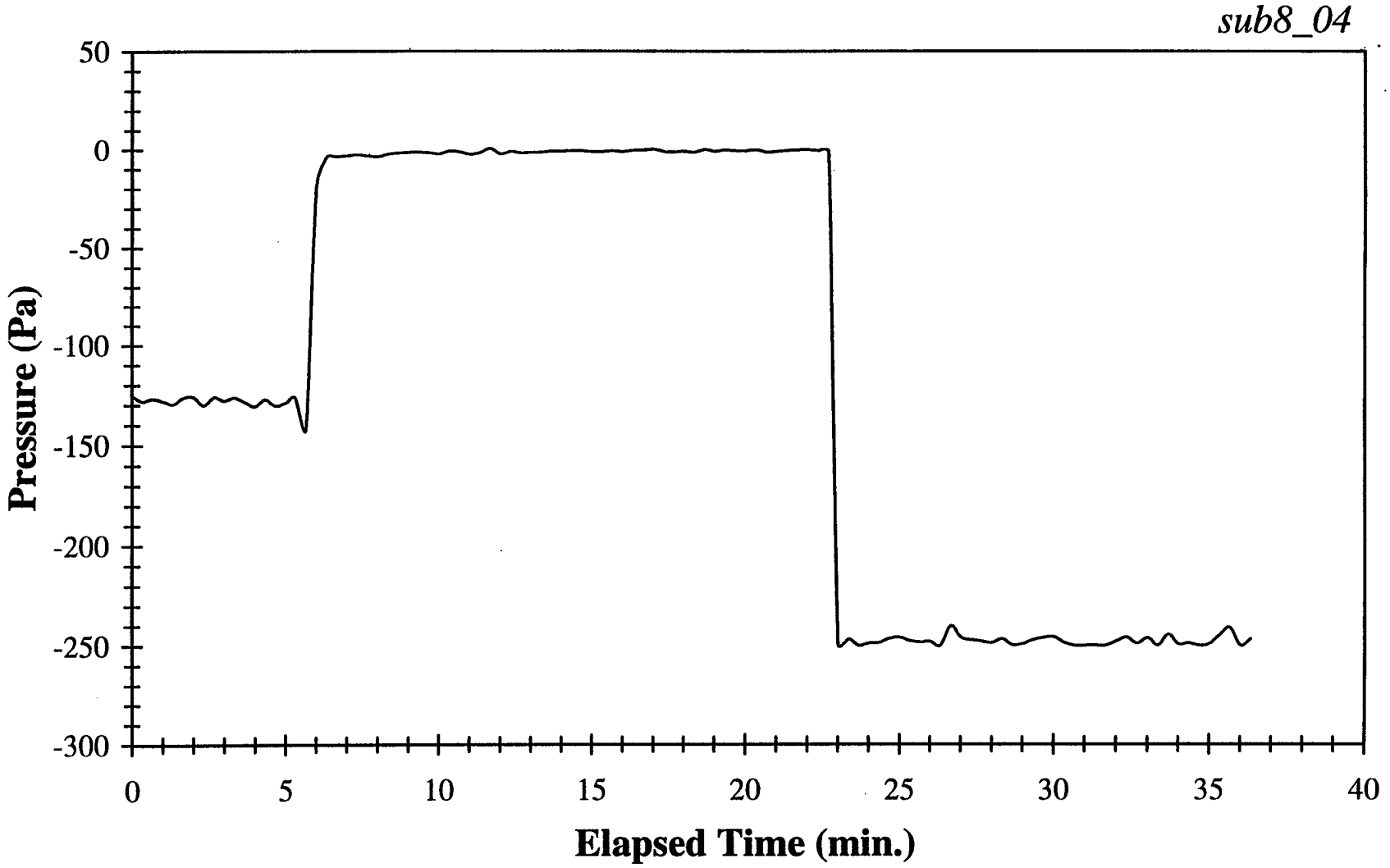

Fig F36 – Differential pressure (high – Fan Room, low – Control Room)

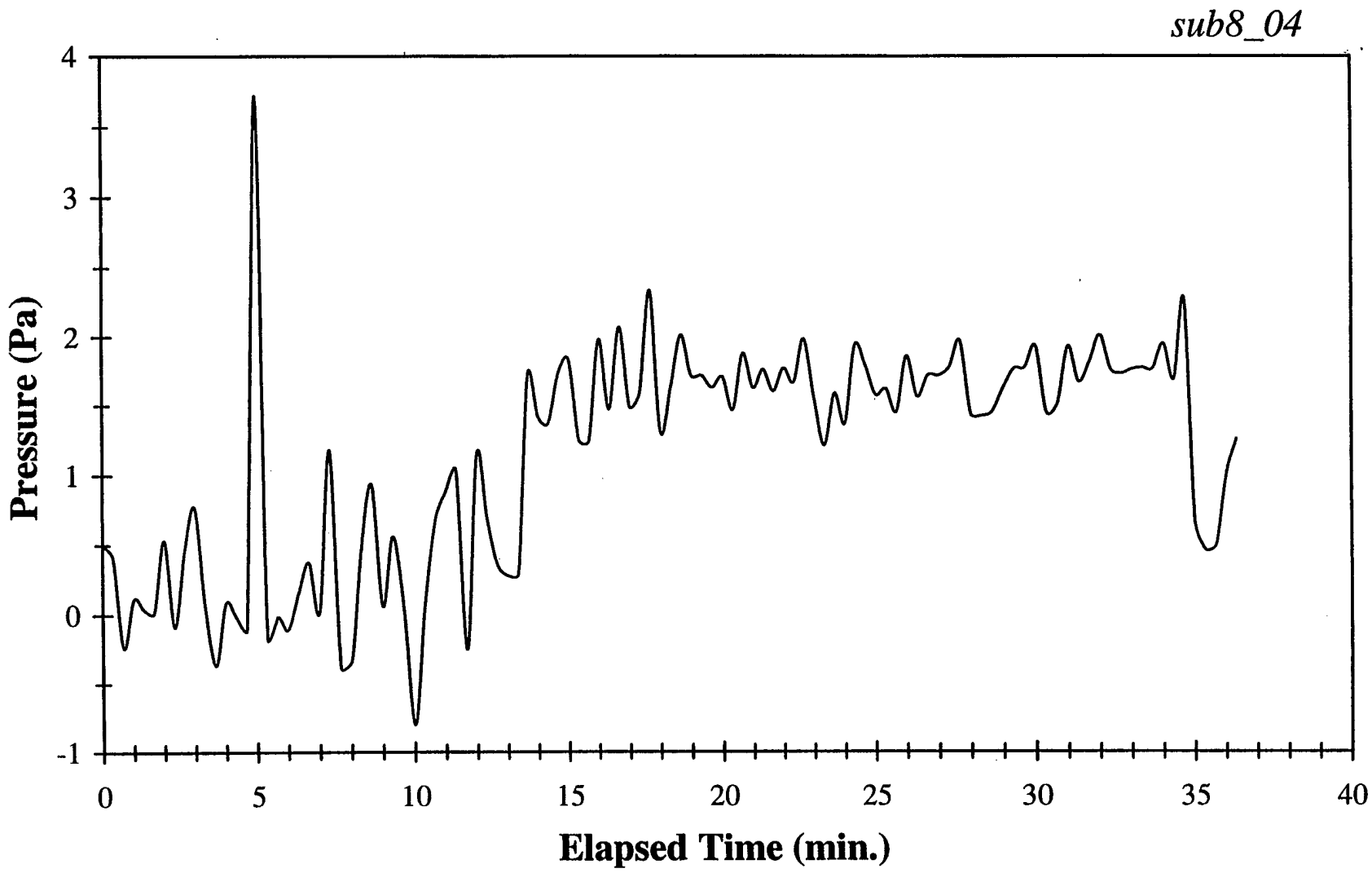

Fig. F37 – Differential pressure (high – Crew Living, low – Combat Systems)

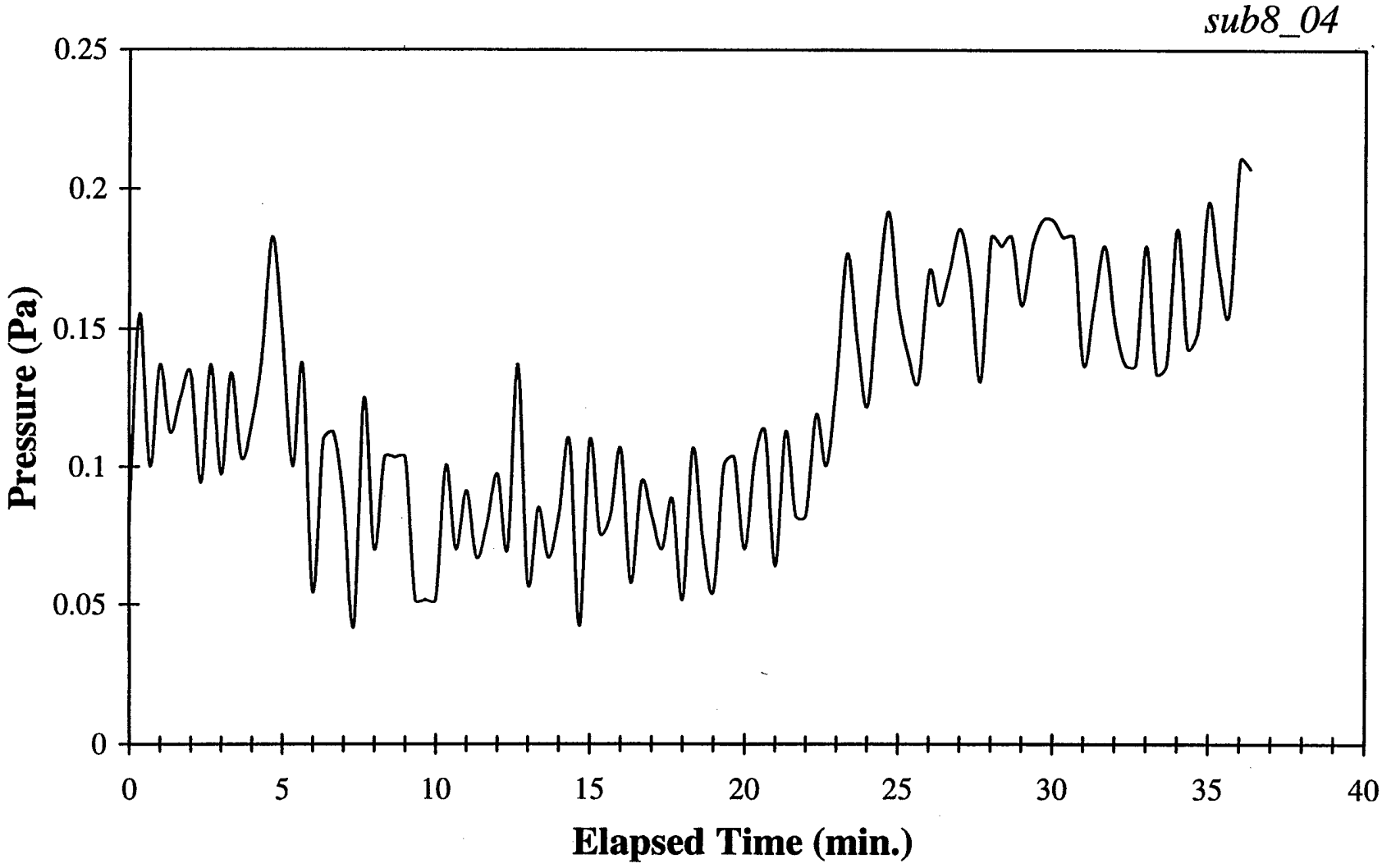

Fig. F38 – Differential pressure (high – CPO/Crew Mess, low – Wardroom)

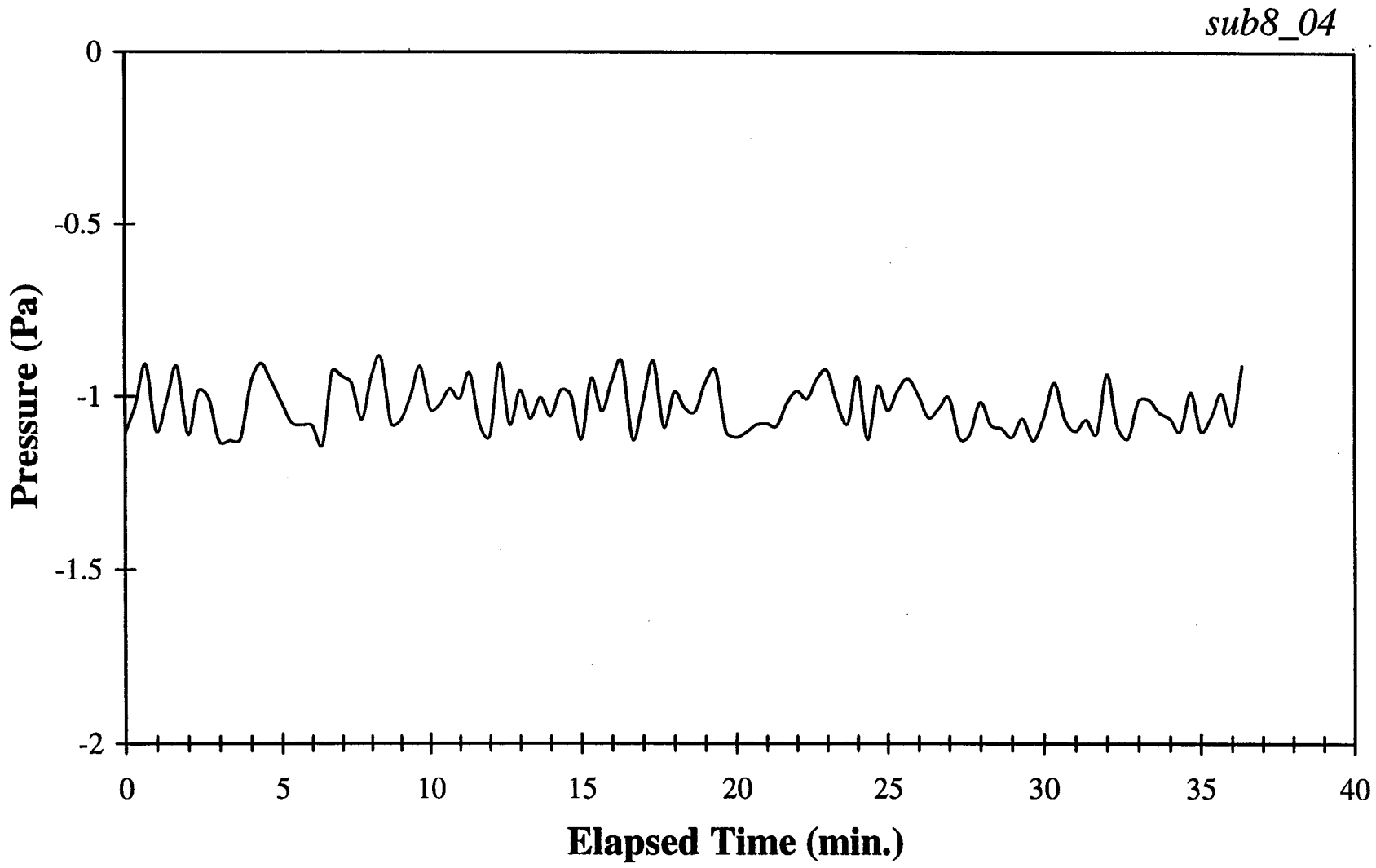

Fig. F39 – Differential pressure (high Torpedo Room, low – Store Room)

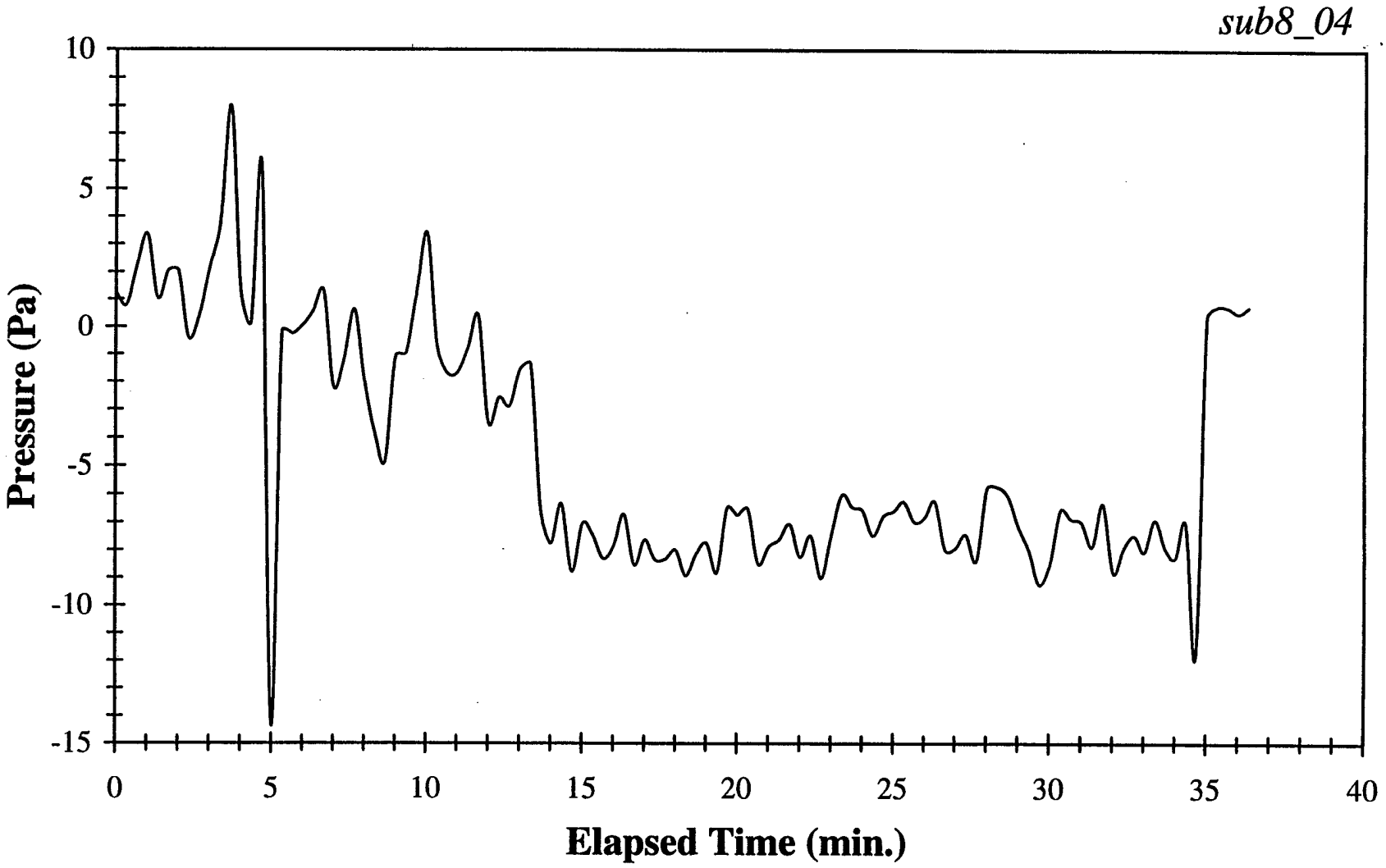

Fig. F40 – Differential pressure (high – Laundry, low – Torpedo Room)

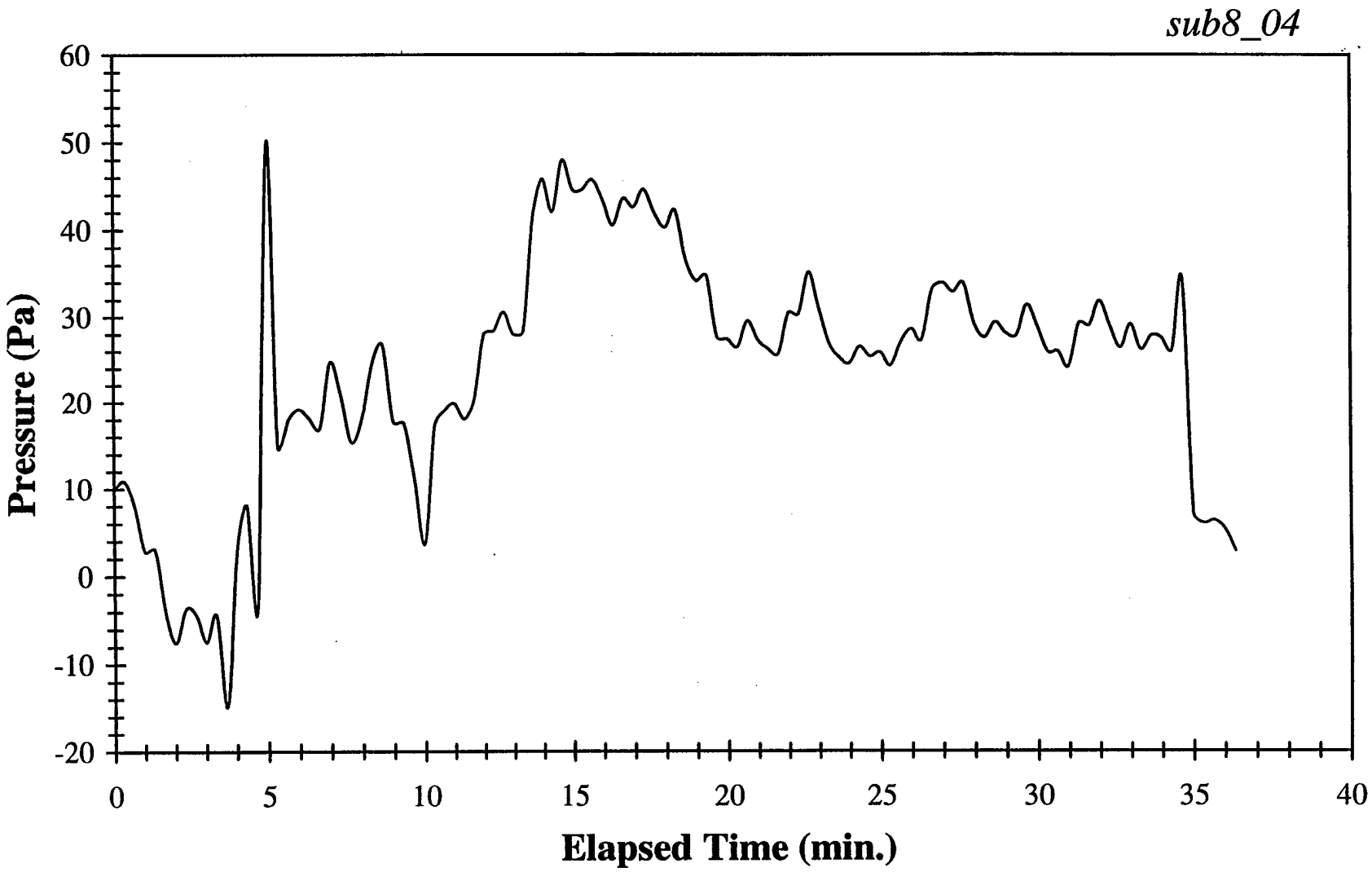

Fig. F41 – Differential pressure (high – Laundry, low – Battery Comp.)

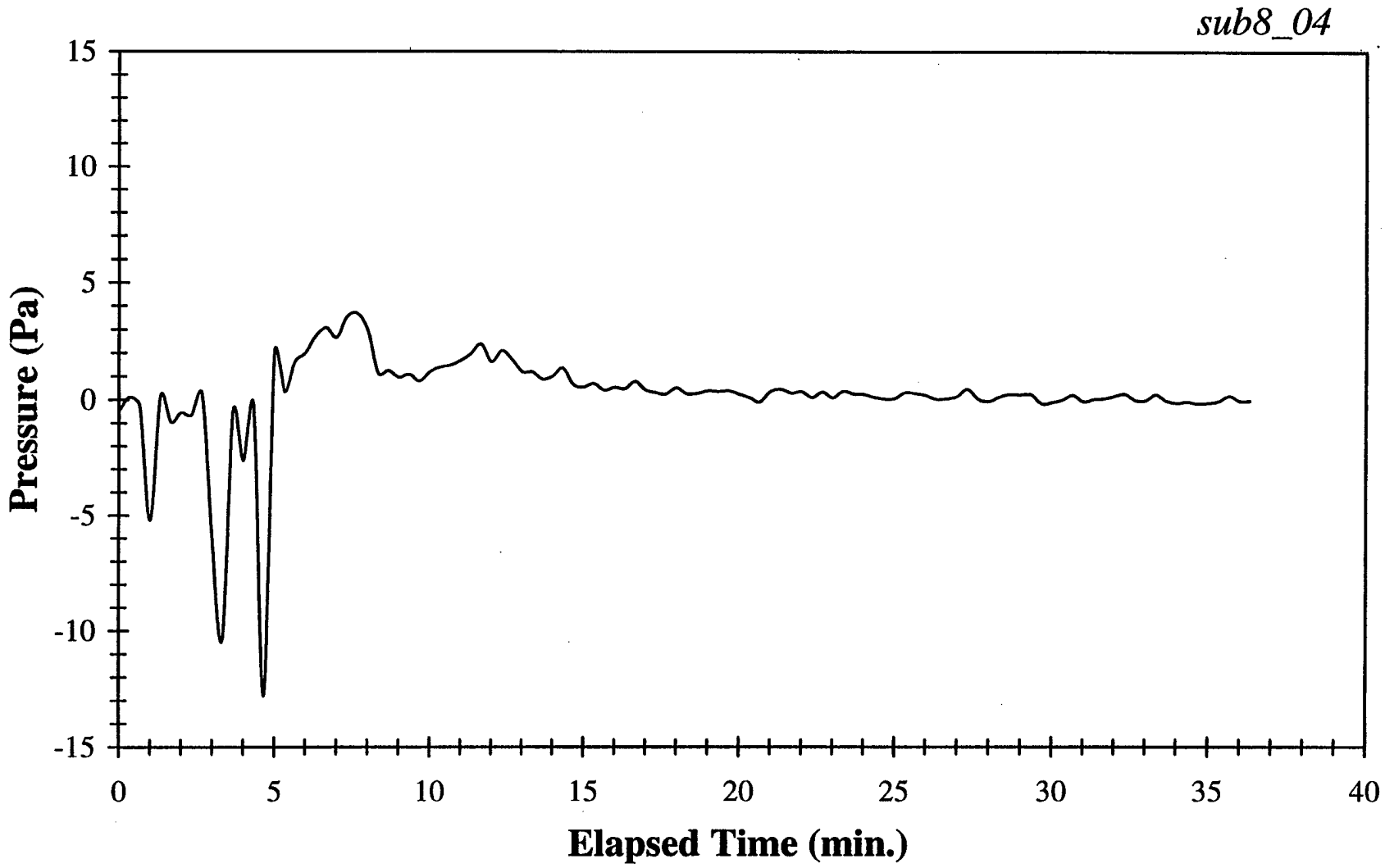

Fig. F42 – Differential pressure (high – AMR, low – Laundry)

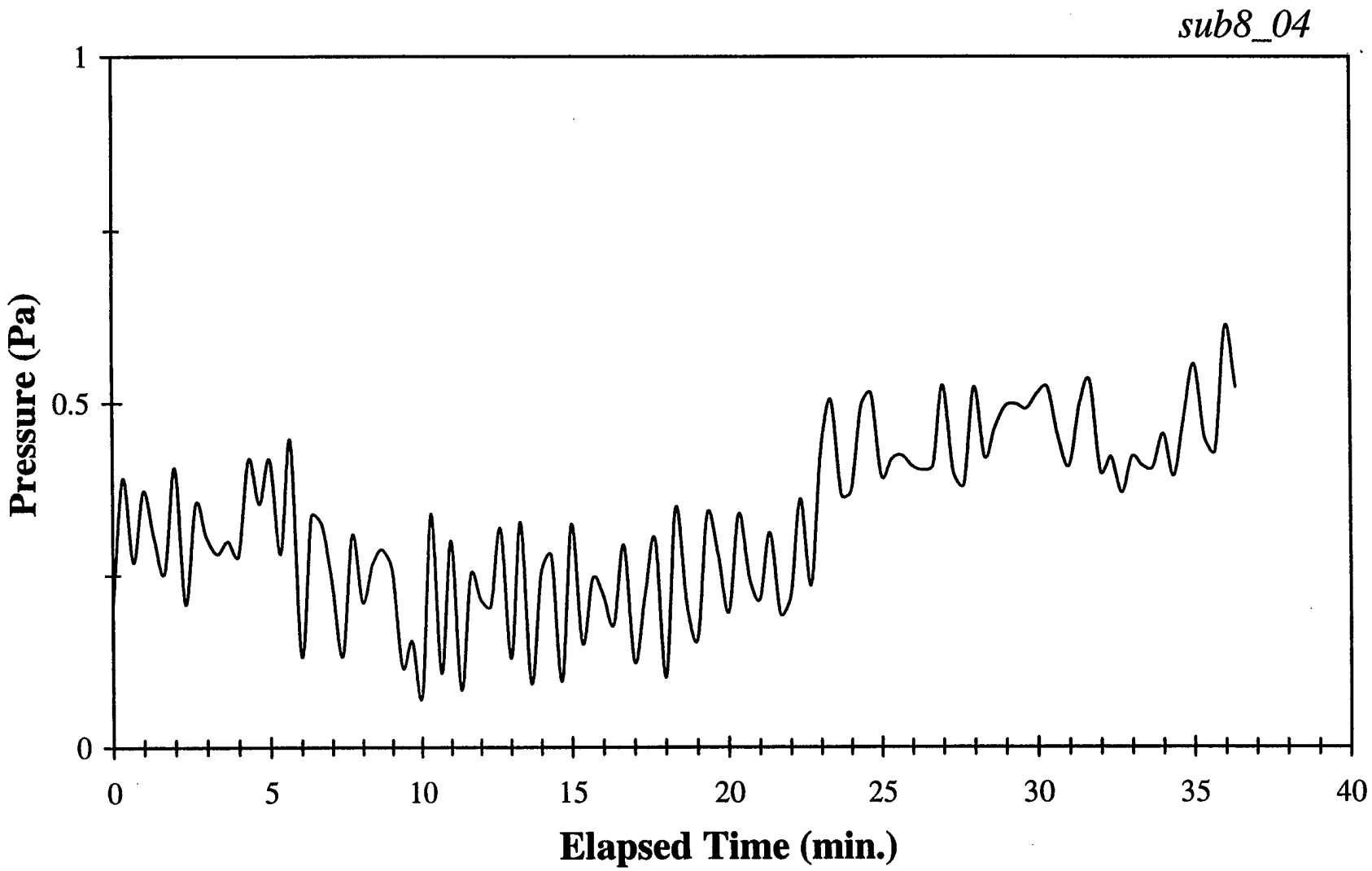

Fig. F43 – Differential pressure (high – Wardroom, low – Control Room)

Diff 2>1-81

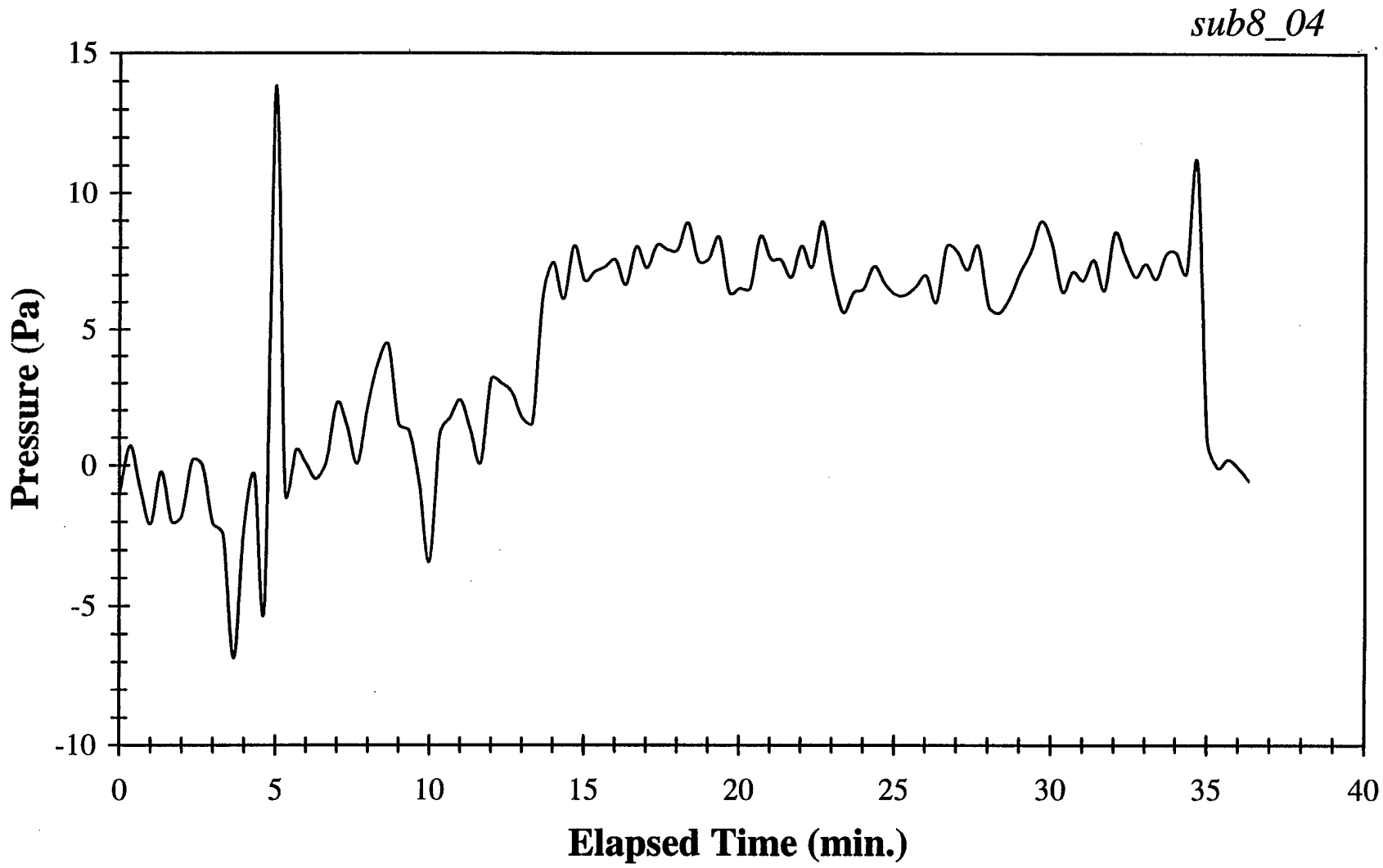

Fig. F44 – Differential pressure (high – Torpedo Room, low – Crew Living)

Diff 3>2-74

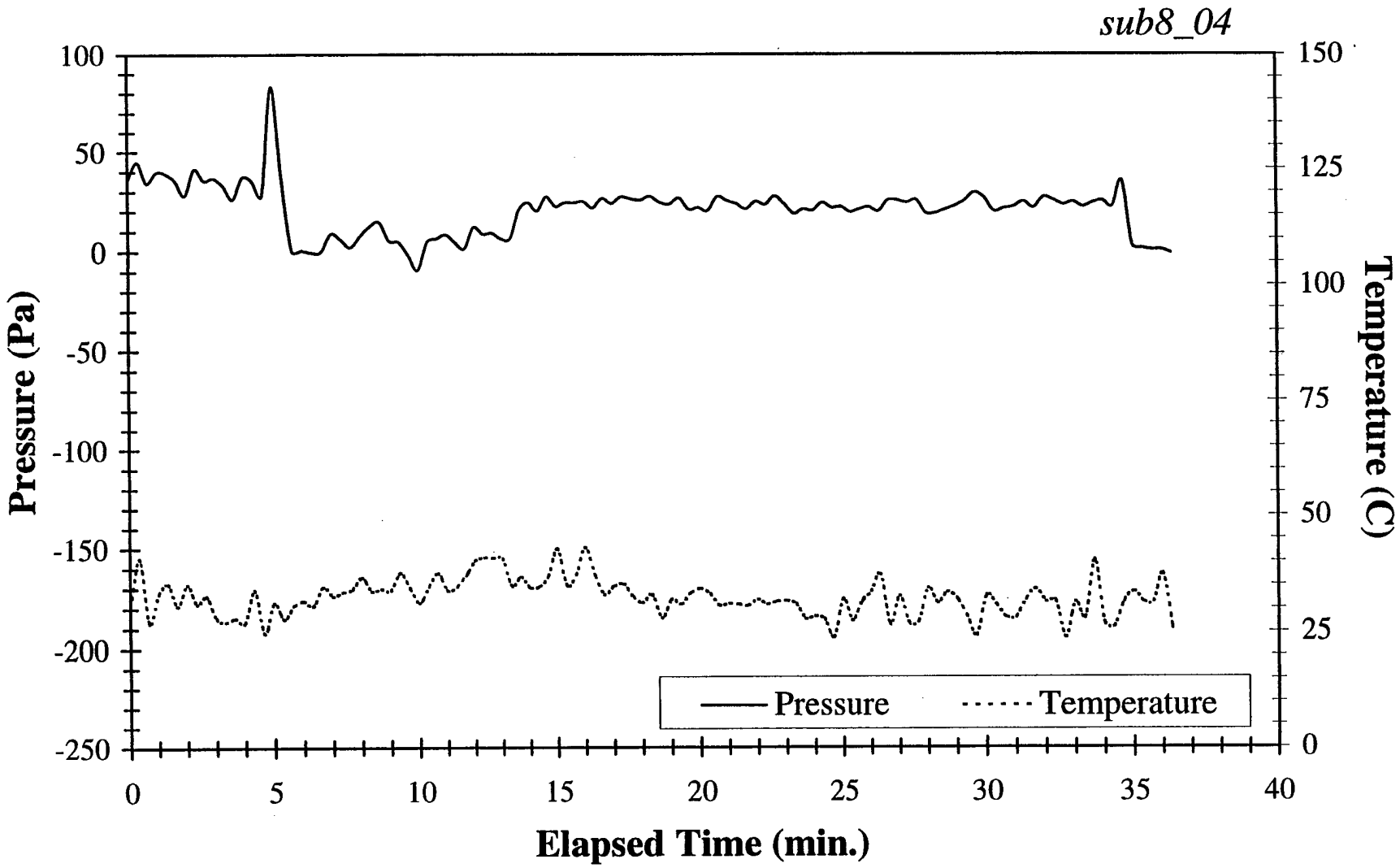

Fig. F45 – Wardroom – Exhaust Vent Duct (bi-flow pressure and temperature)

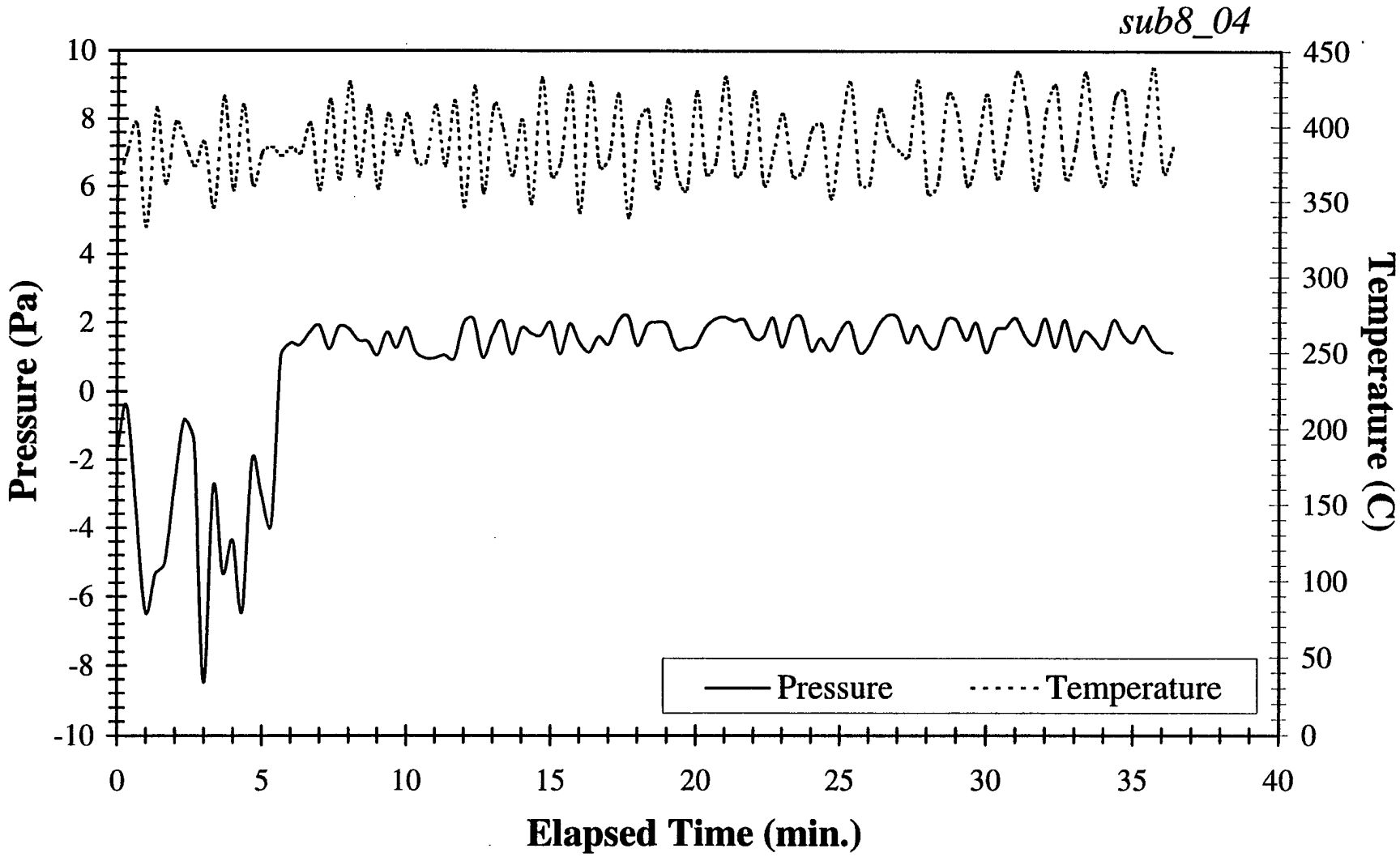

Fig. F46 – Laundry – Exhaust Vent Duct (bi–flow pressue and temperature)

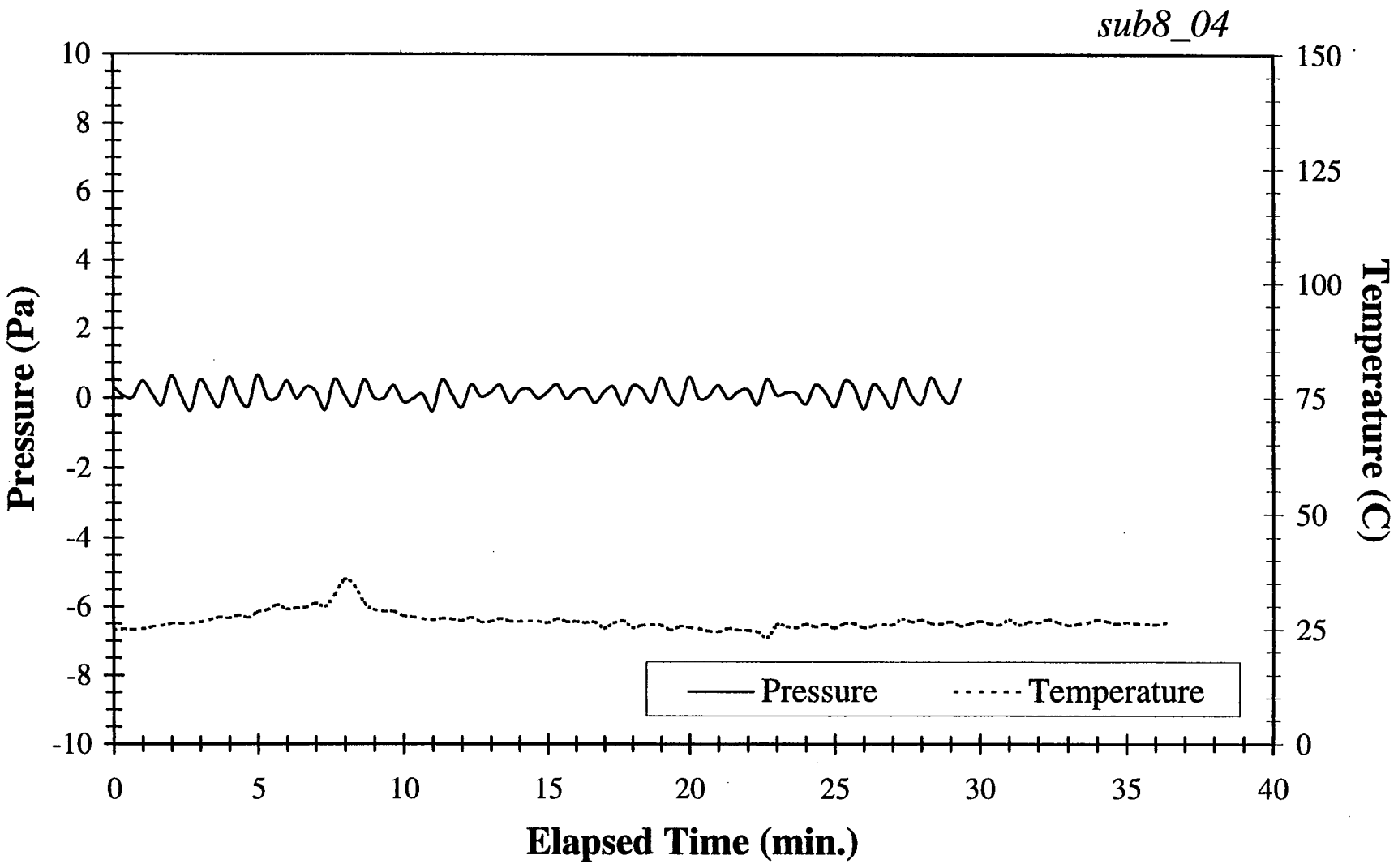

Fig. F47 – AMR – Supply Vent Duct (bi-flow pressure and temperature)

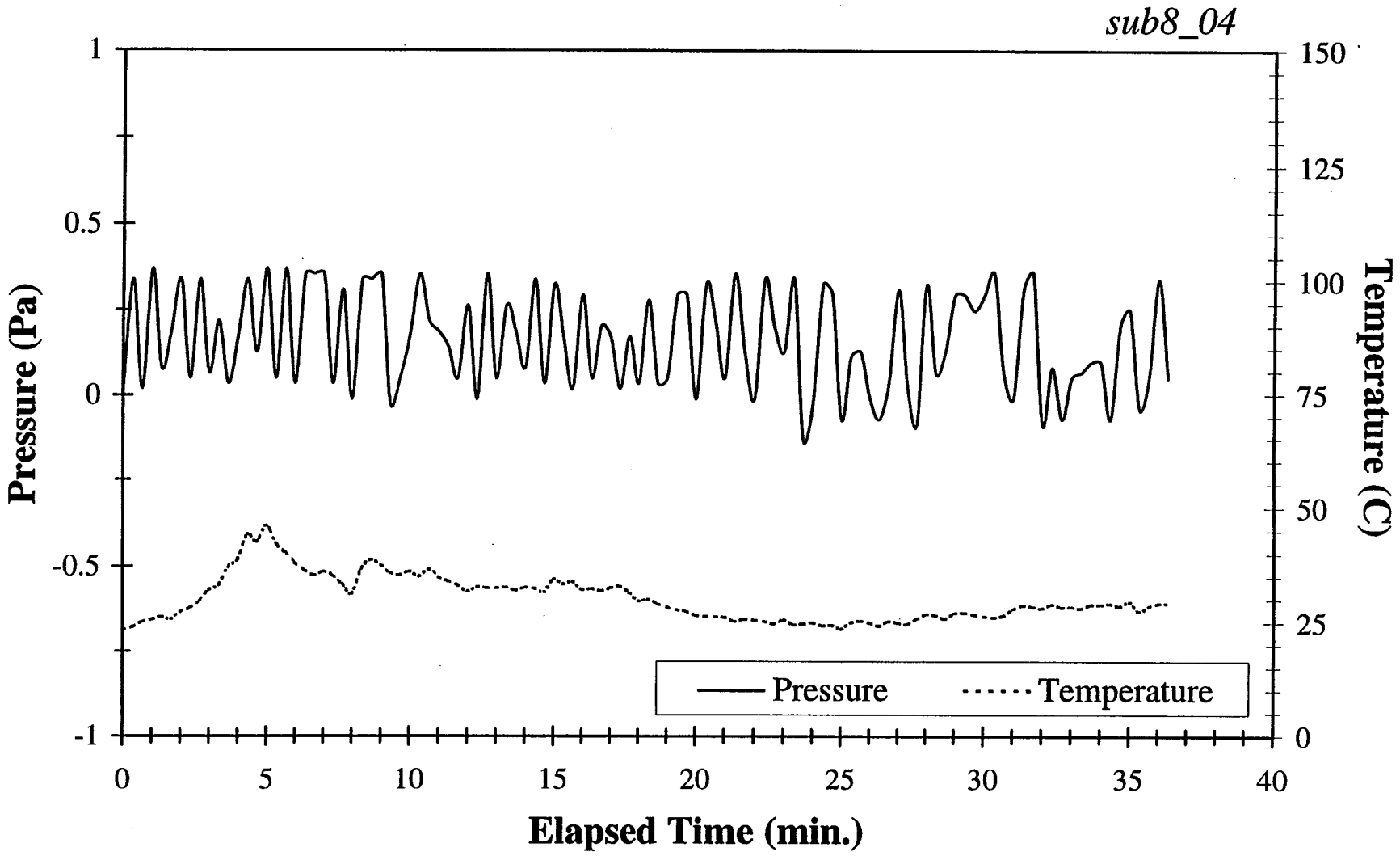

Fig. F48 – AMR – Exhaust Vent Duct (bi-flow pressure and temperature)

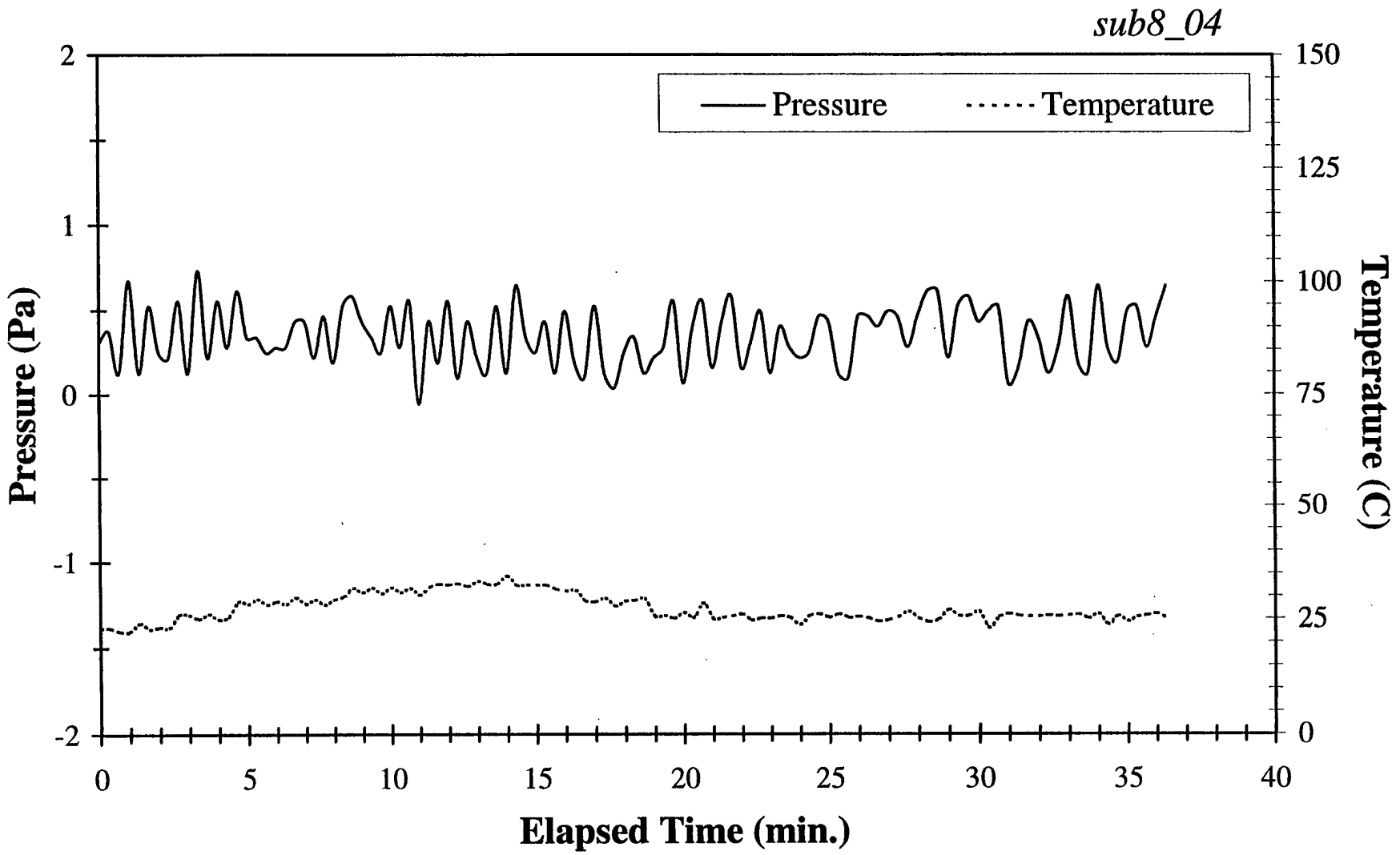

Fig. F49 - Supply Vent Duct (bi-flow pressure and tempeature)

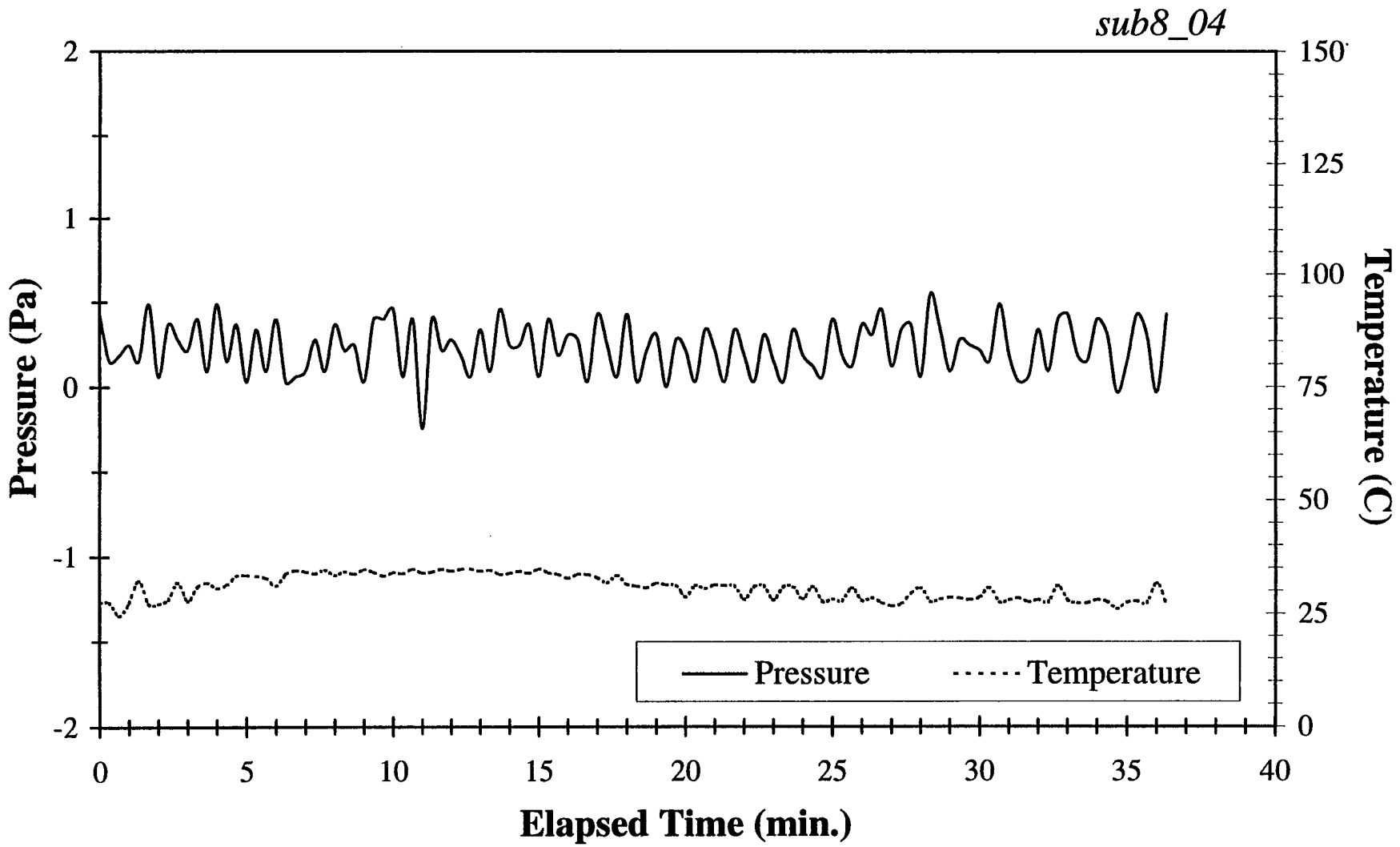

Fig. F50 – Exhaust Vent Duct (bi-flow pressure and temperature)

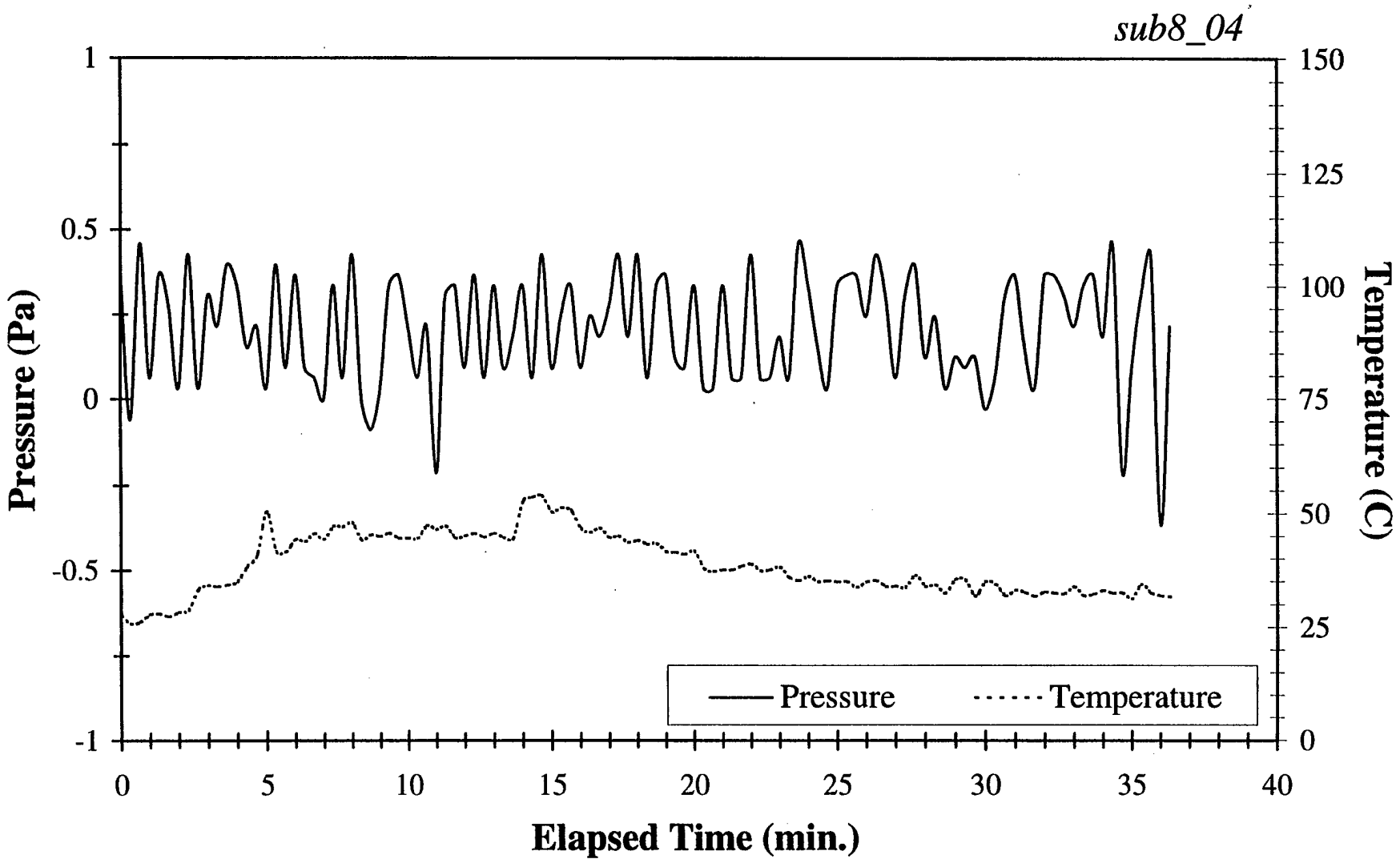

Fig. F51 – L.P. Blower Exhaust Duct (bi-flow pressure and temperature)

L.P. Exh.

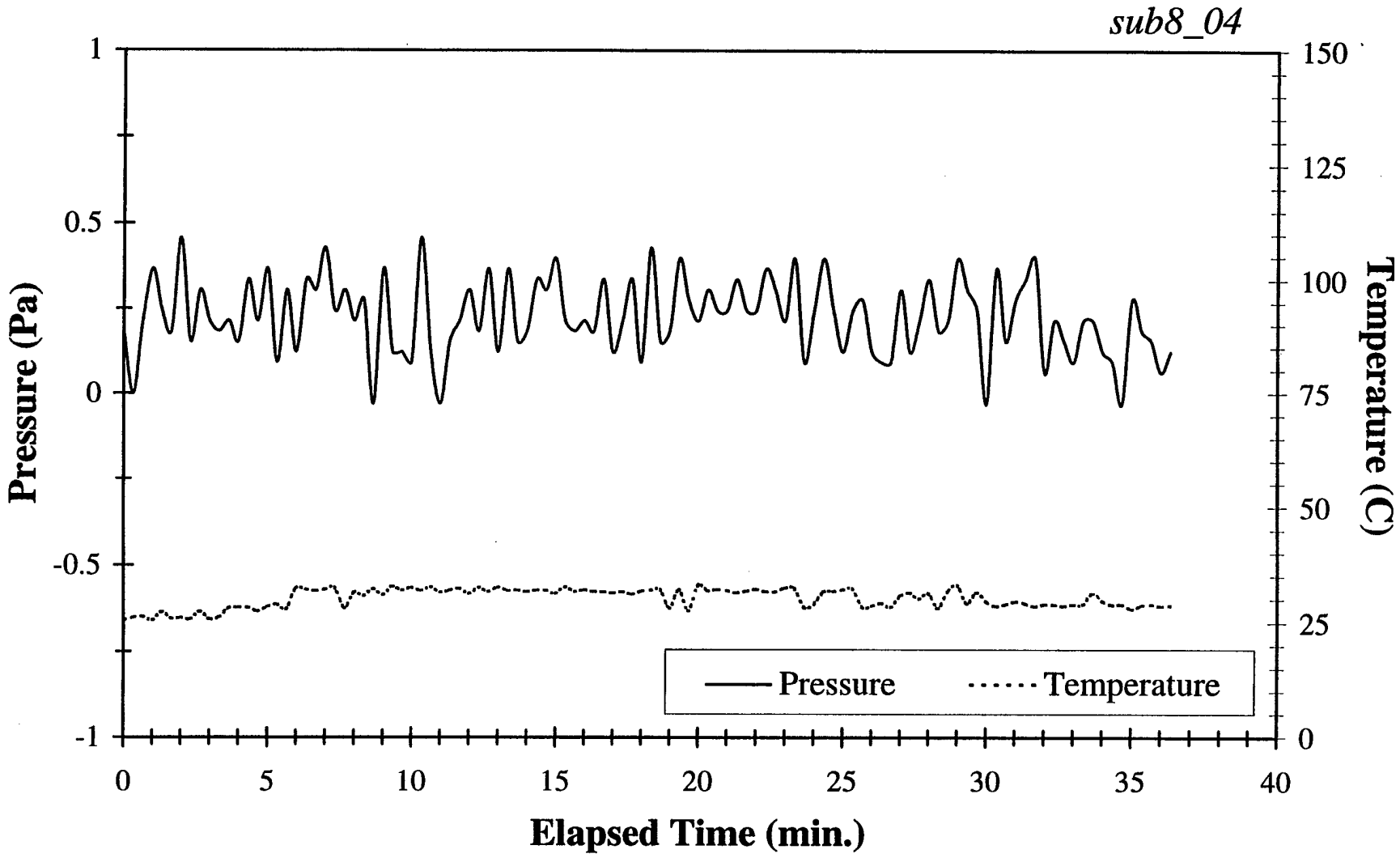

Fig. F52 – Induction System Duct (bi-flow pressure and temperature)

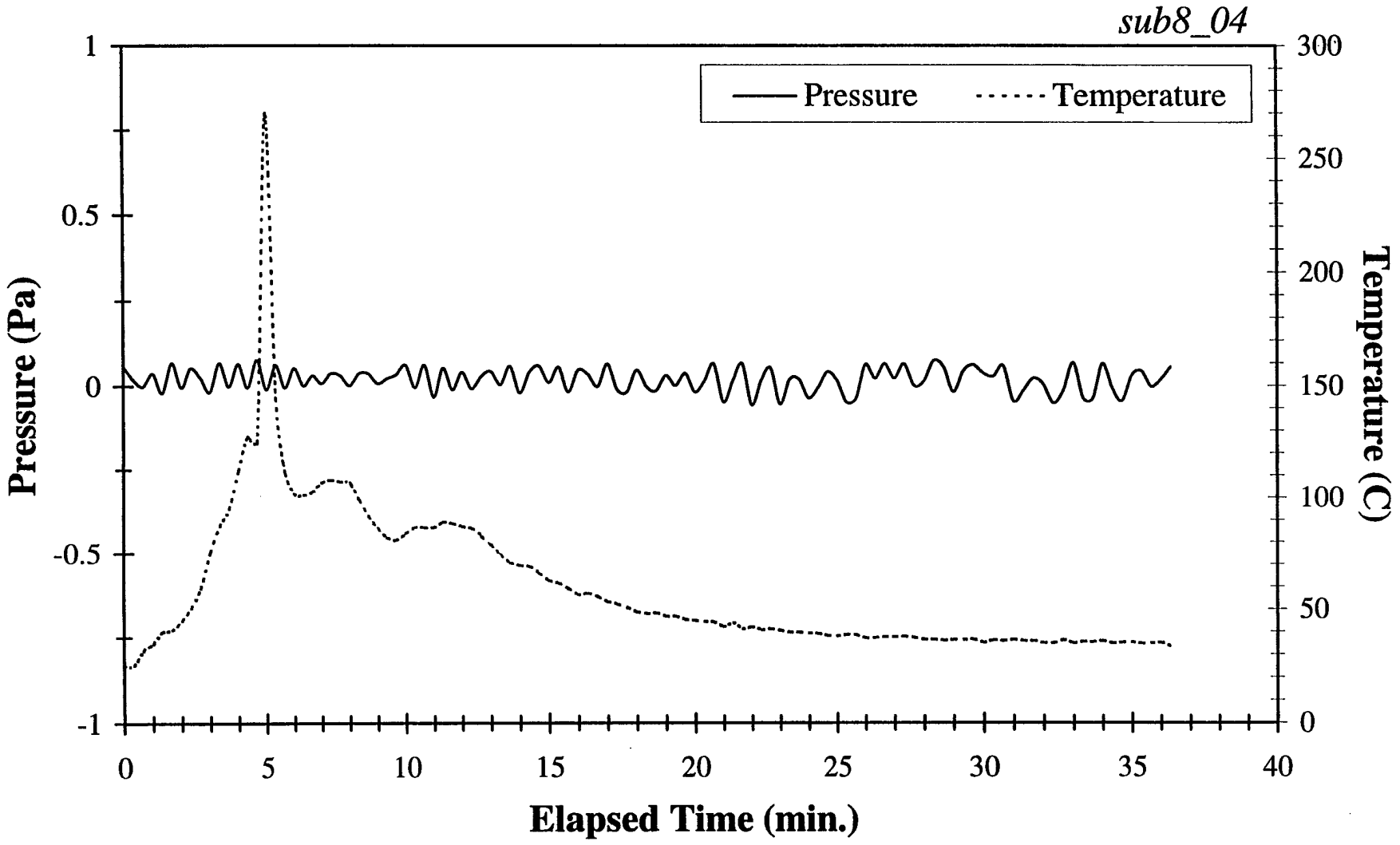

Fig. F53 - Fan Room - Total Flow through FR89 and FR90 Frame Bays (bi-flow pressure and temperature)

FR90 Fan Room

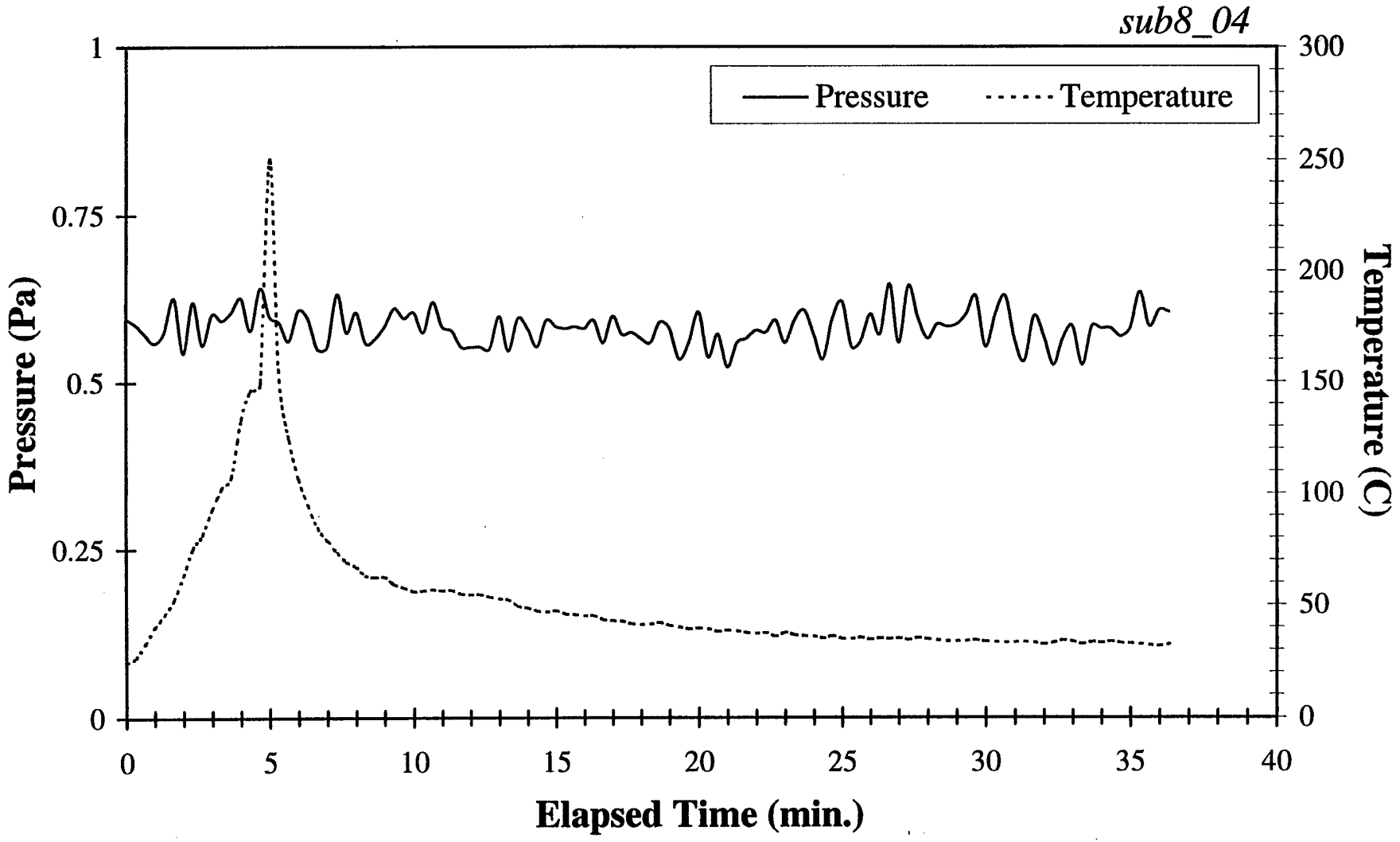

Fig. F54 – CPO/Crew Mess – flow through FR90 Frame Bay
(bi-flow pressure and temperature)

FR90 Mess

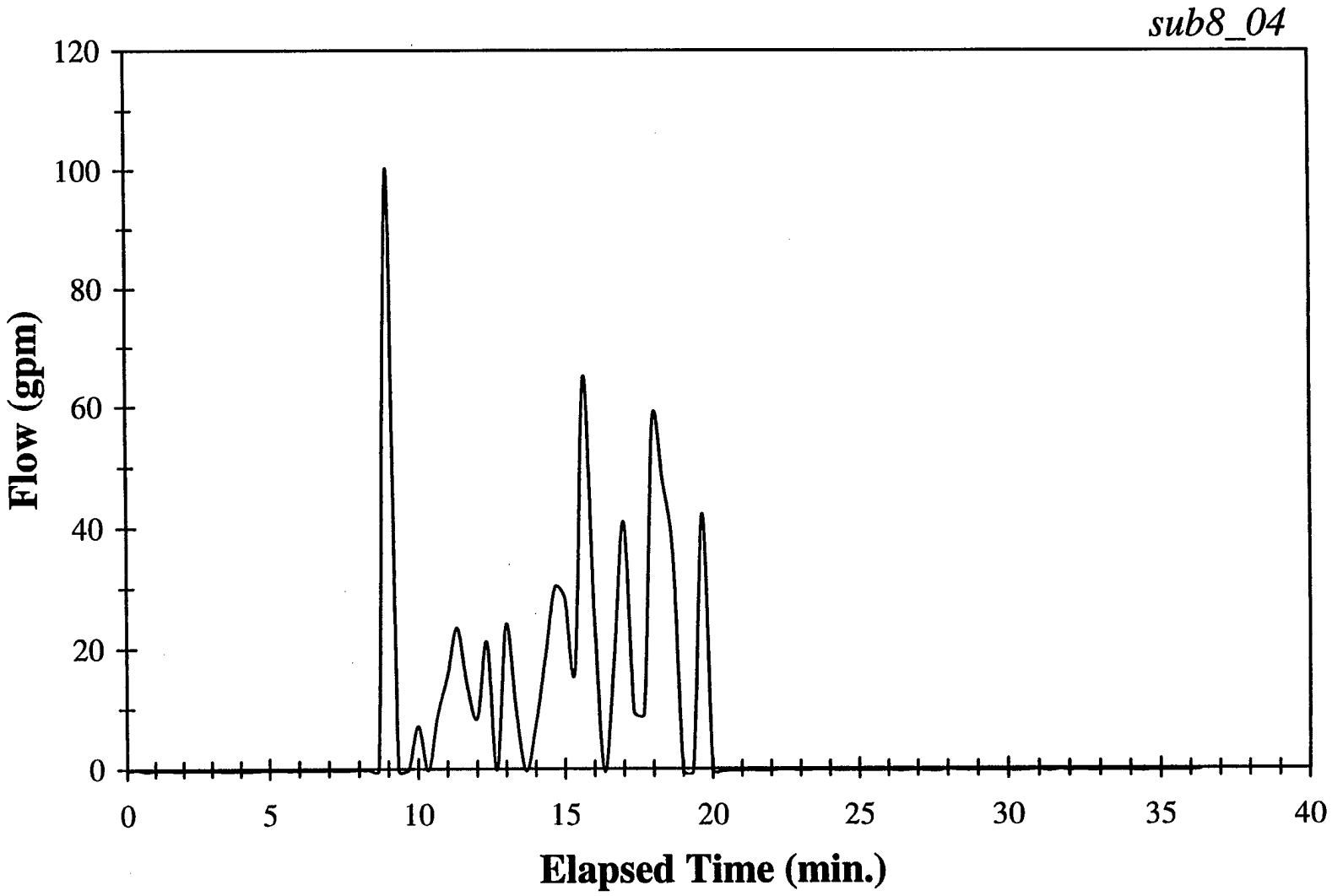

Fig. F55 – Firemain flow rate

Firemain Flowrate

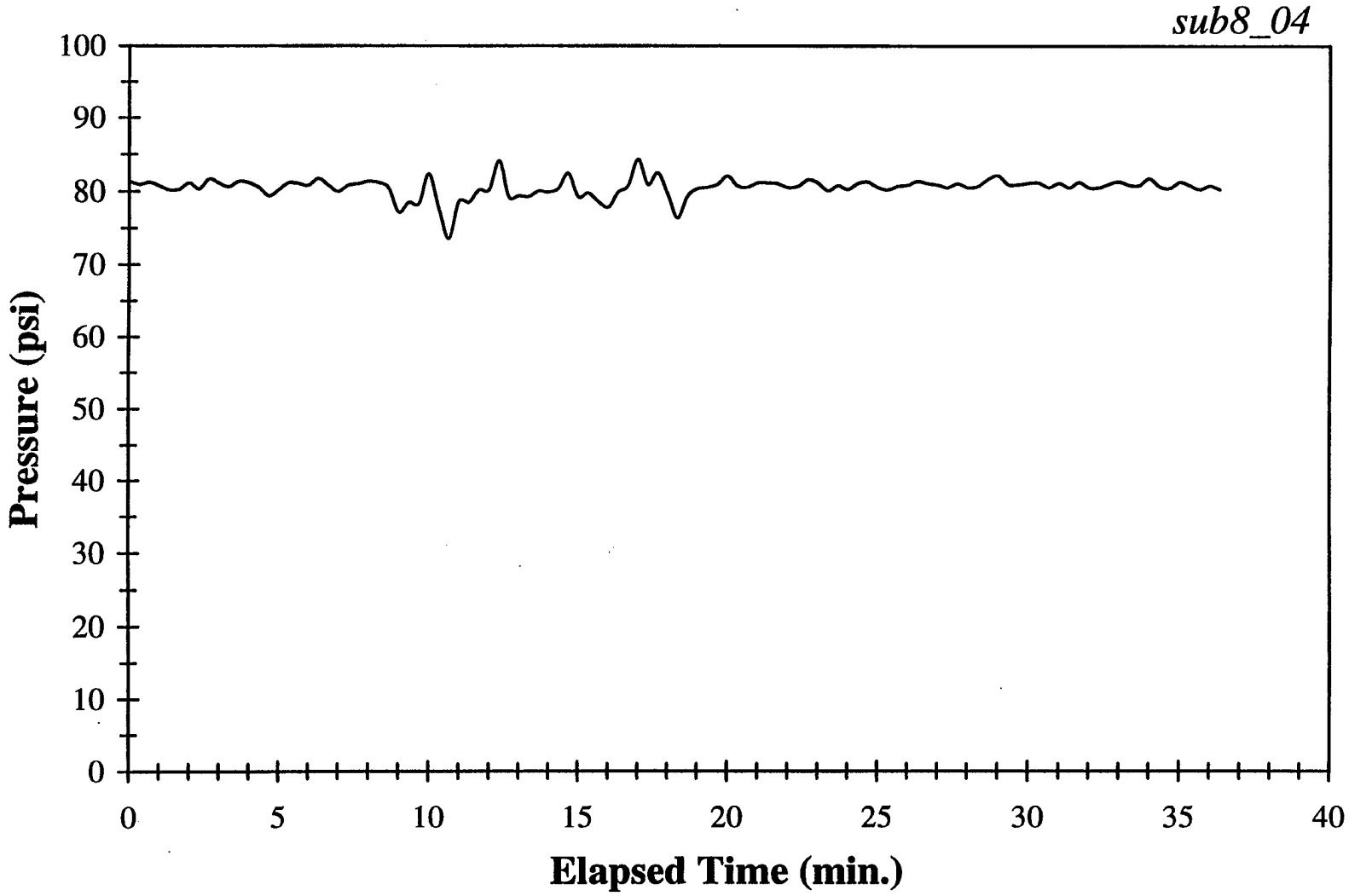

Fig. F56 – Firemain pressure

Appendix G

Measure of Performance Data

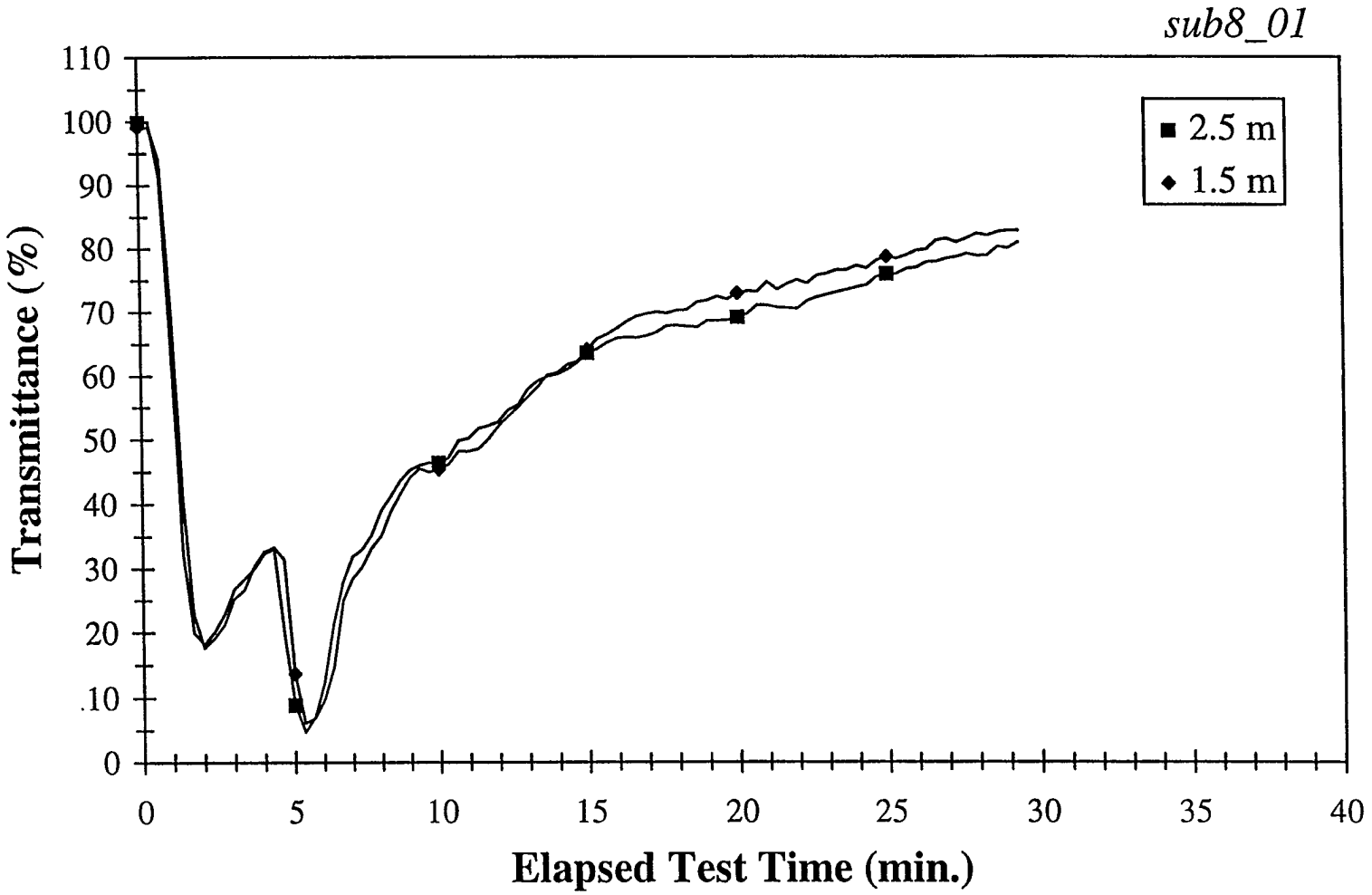

Fig. G1 – Control Room visibility

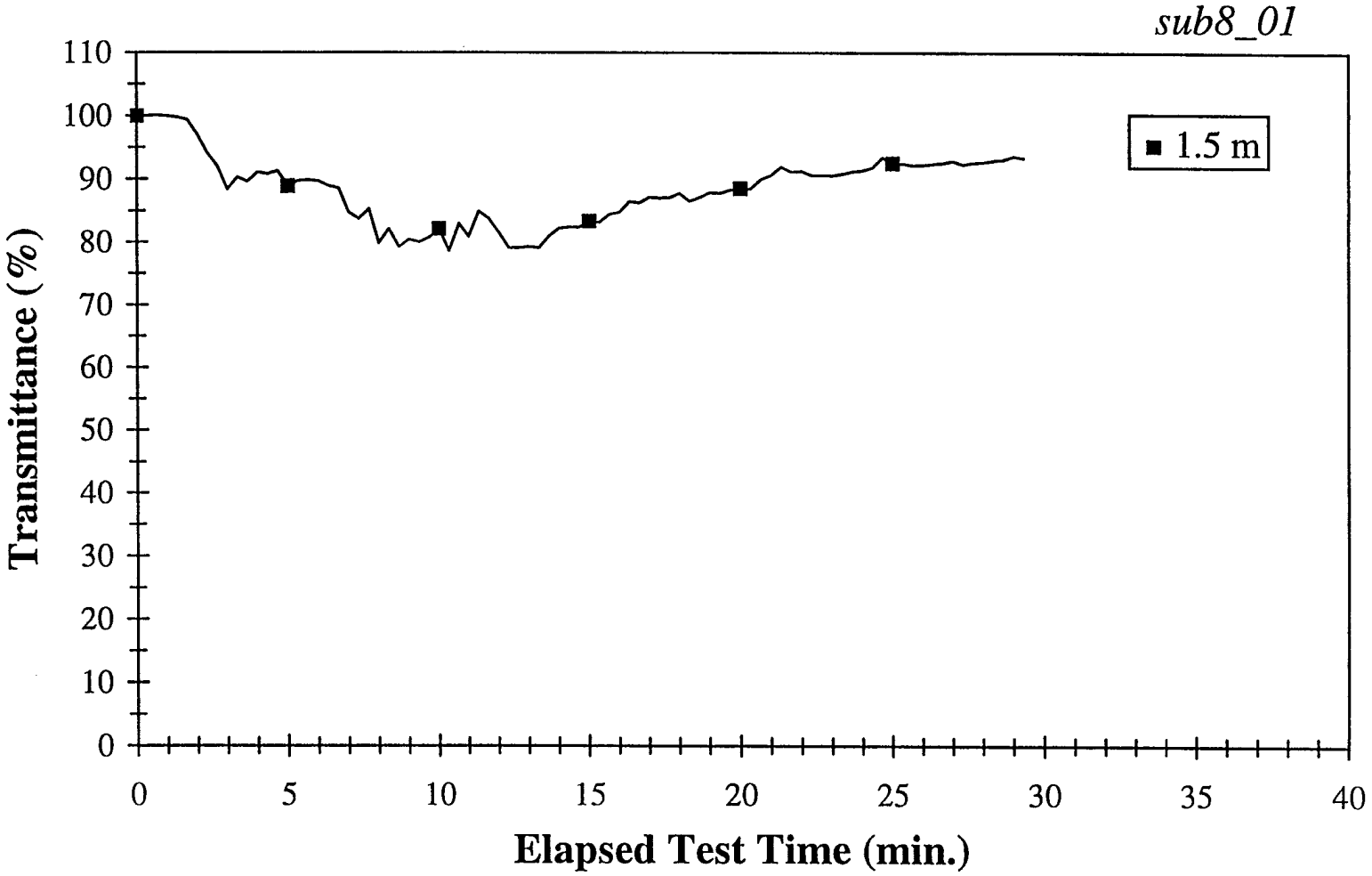

Fig. G2 - CPO/Crew Mess visibility

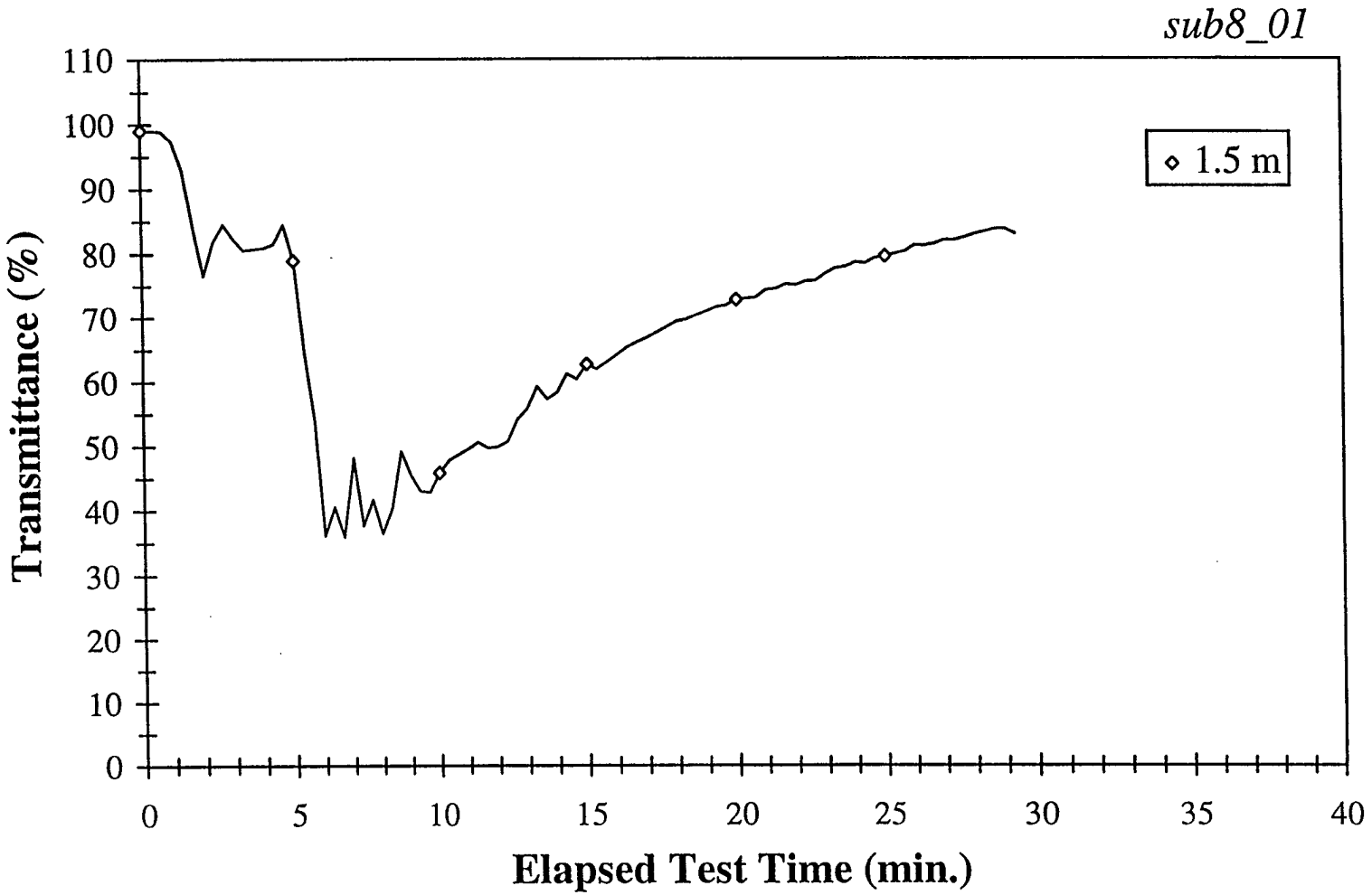

Fig. G3 – Laundry visibility

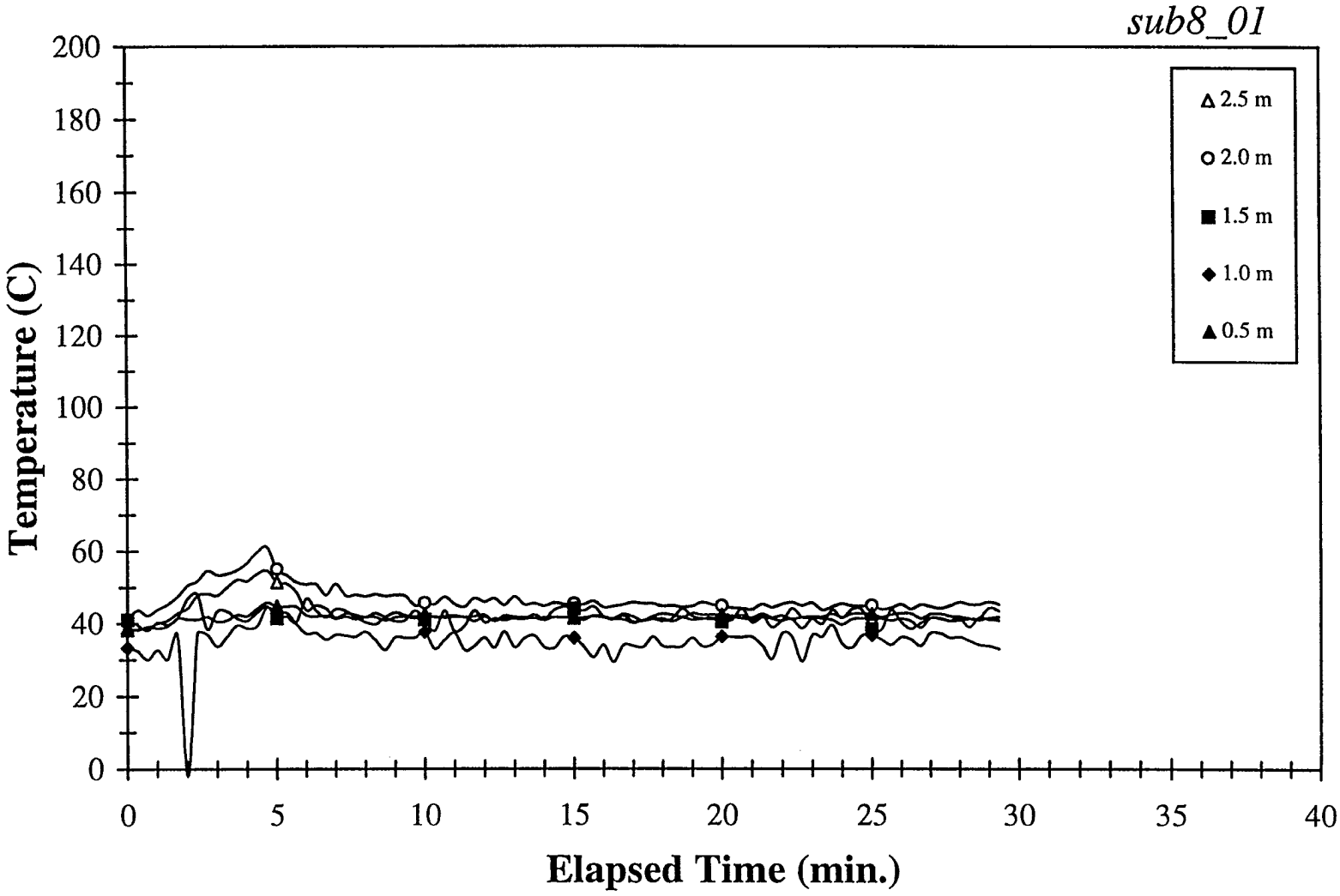

Fig. G4 – Control Room – Aft TC Tree

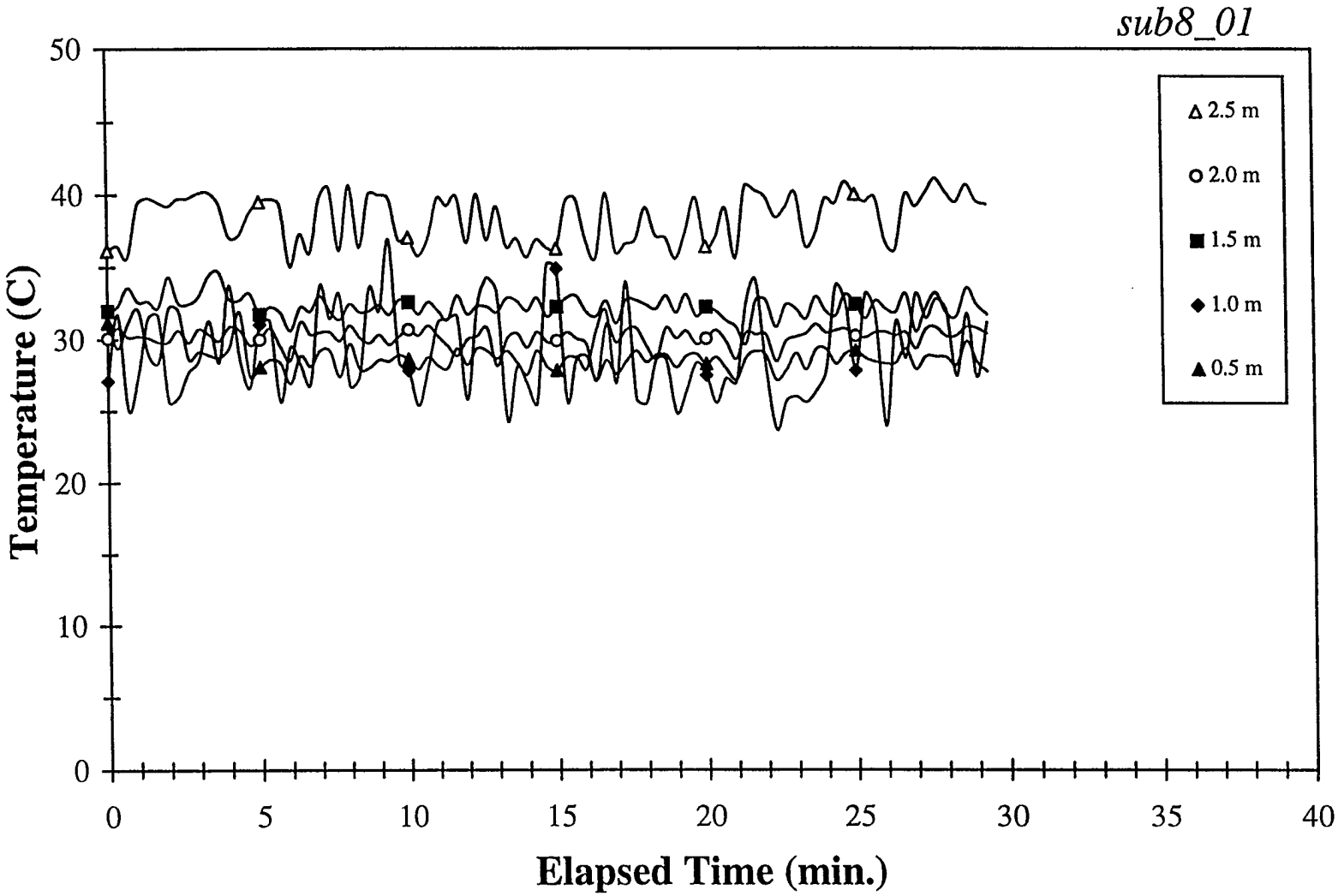

Fig. G5 - CPO/Crew Mess - Aft TC Tree

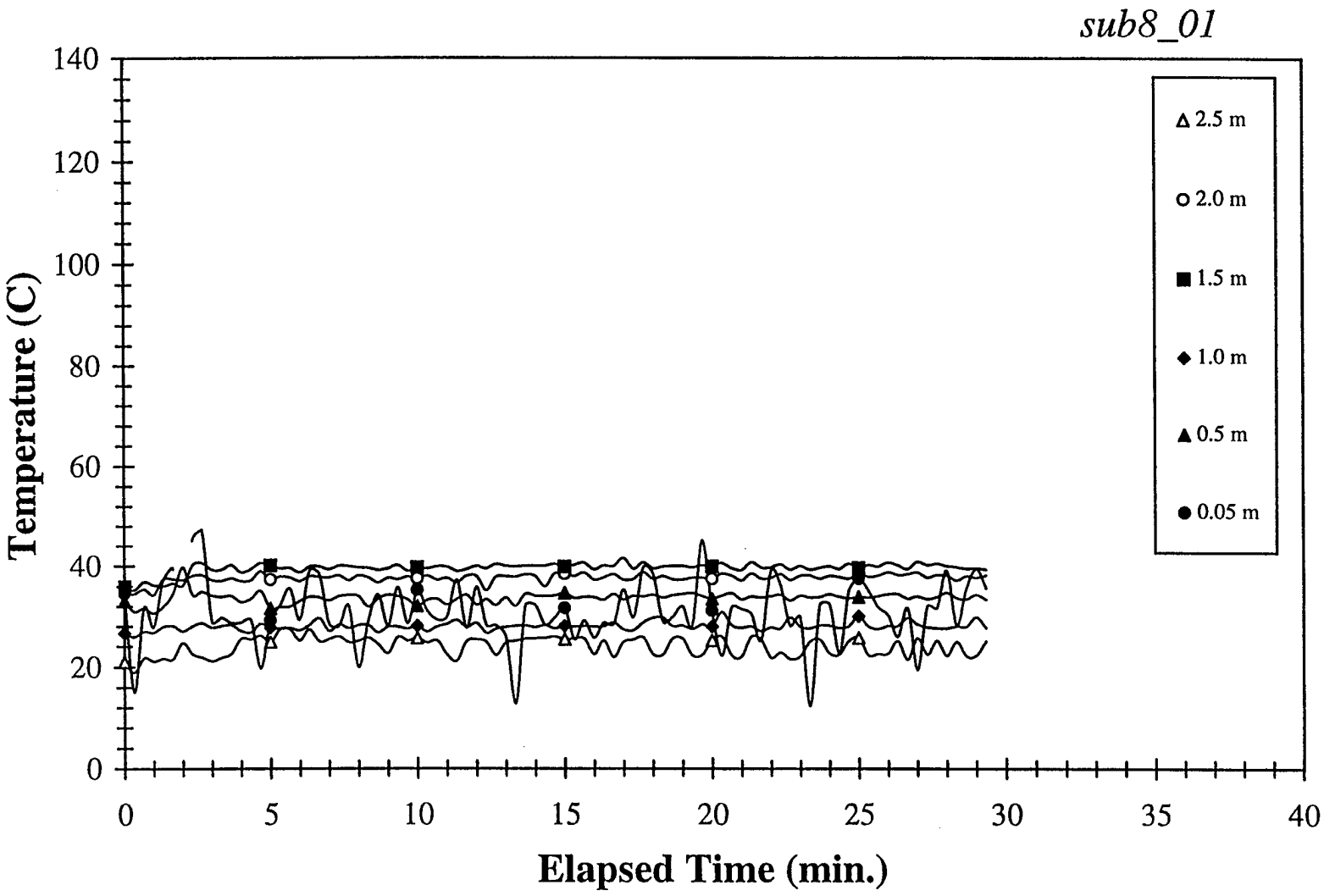

Fig. G6 - Laundry - Aft TC Tree

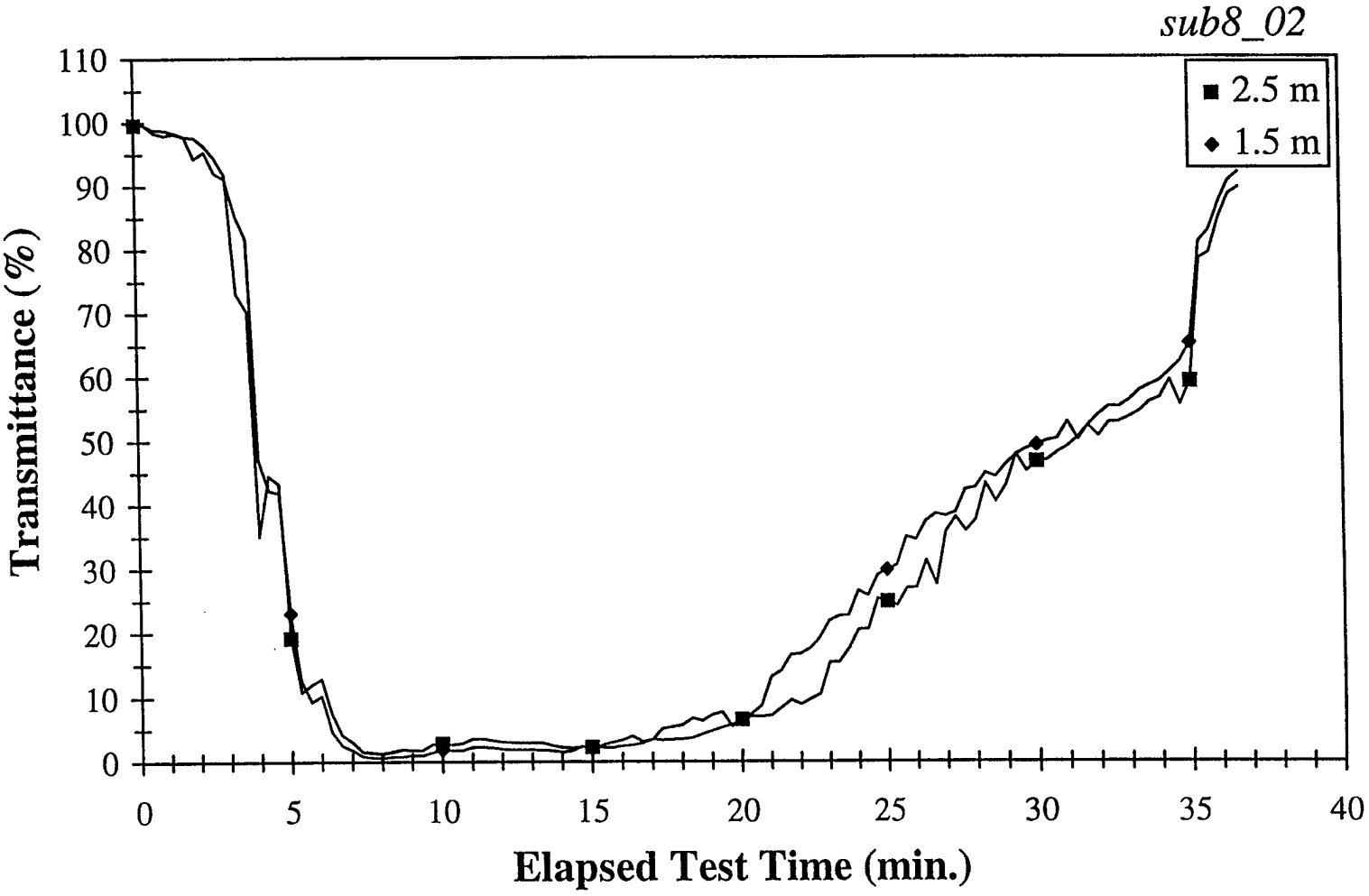

Fig. G7 – Control Room visibility

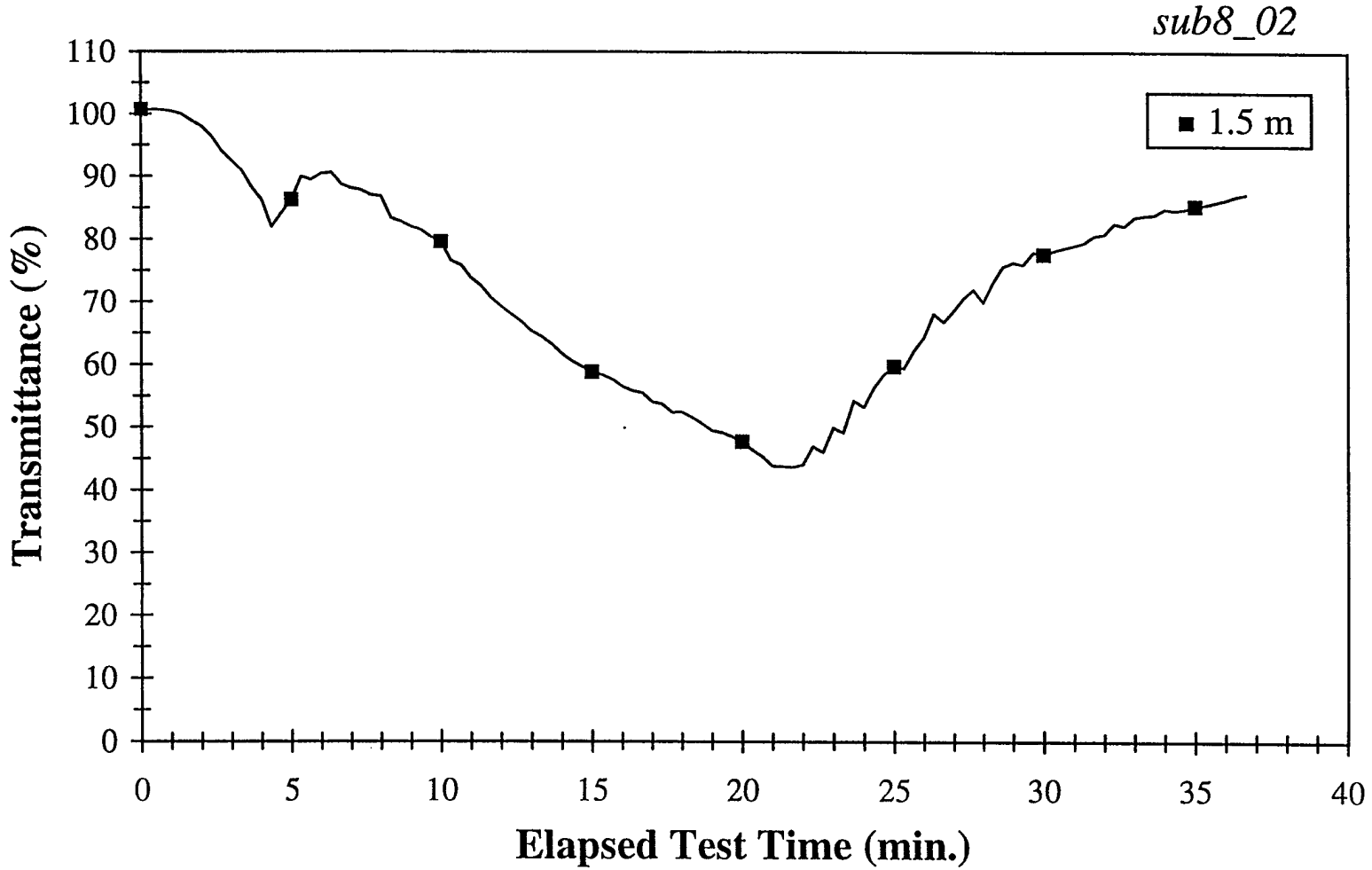

Fig. G8 - CPO/Crew Mess visibility

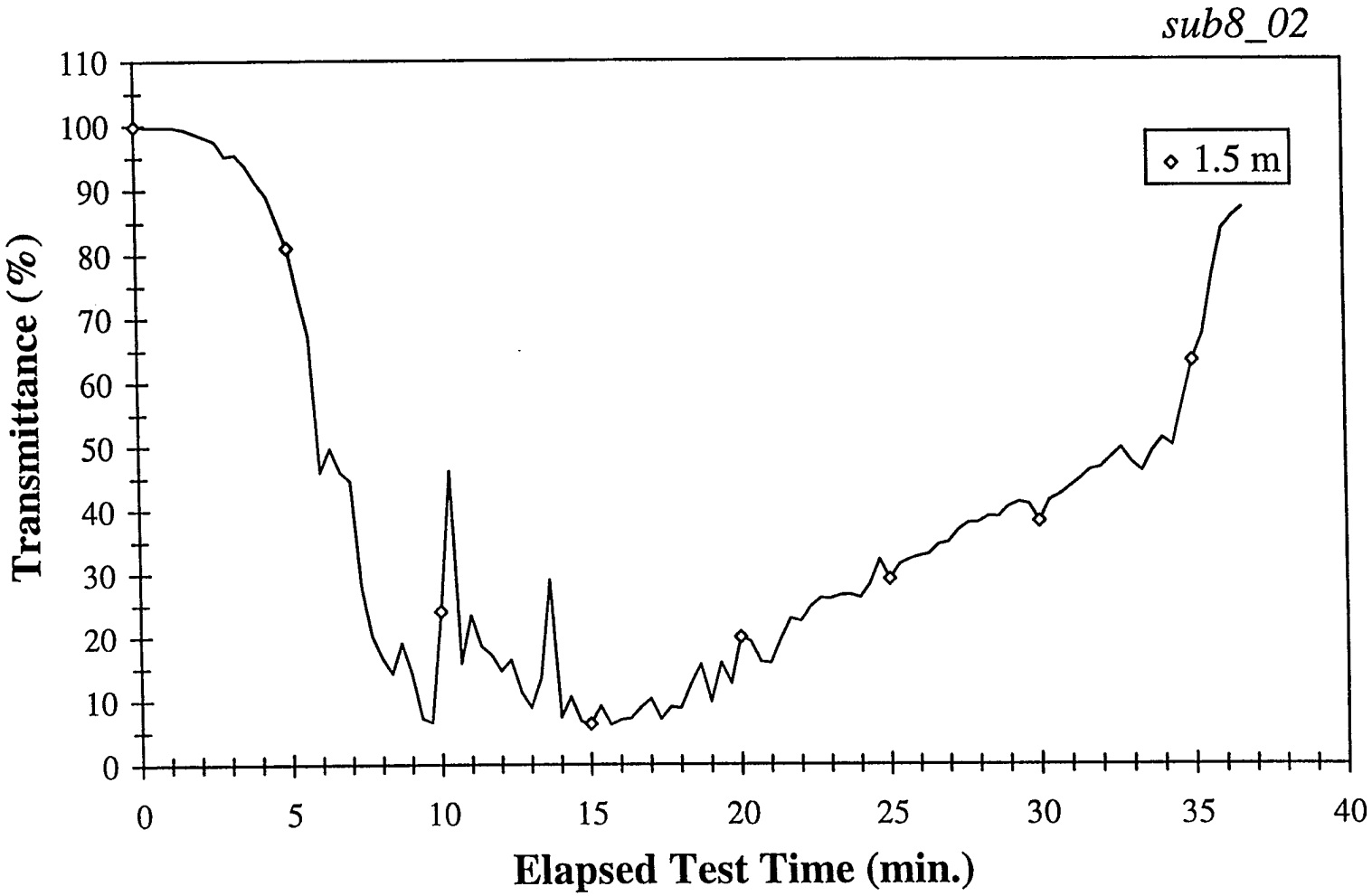

Fig. G9 – Laundry visibility

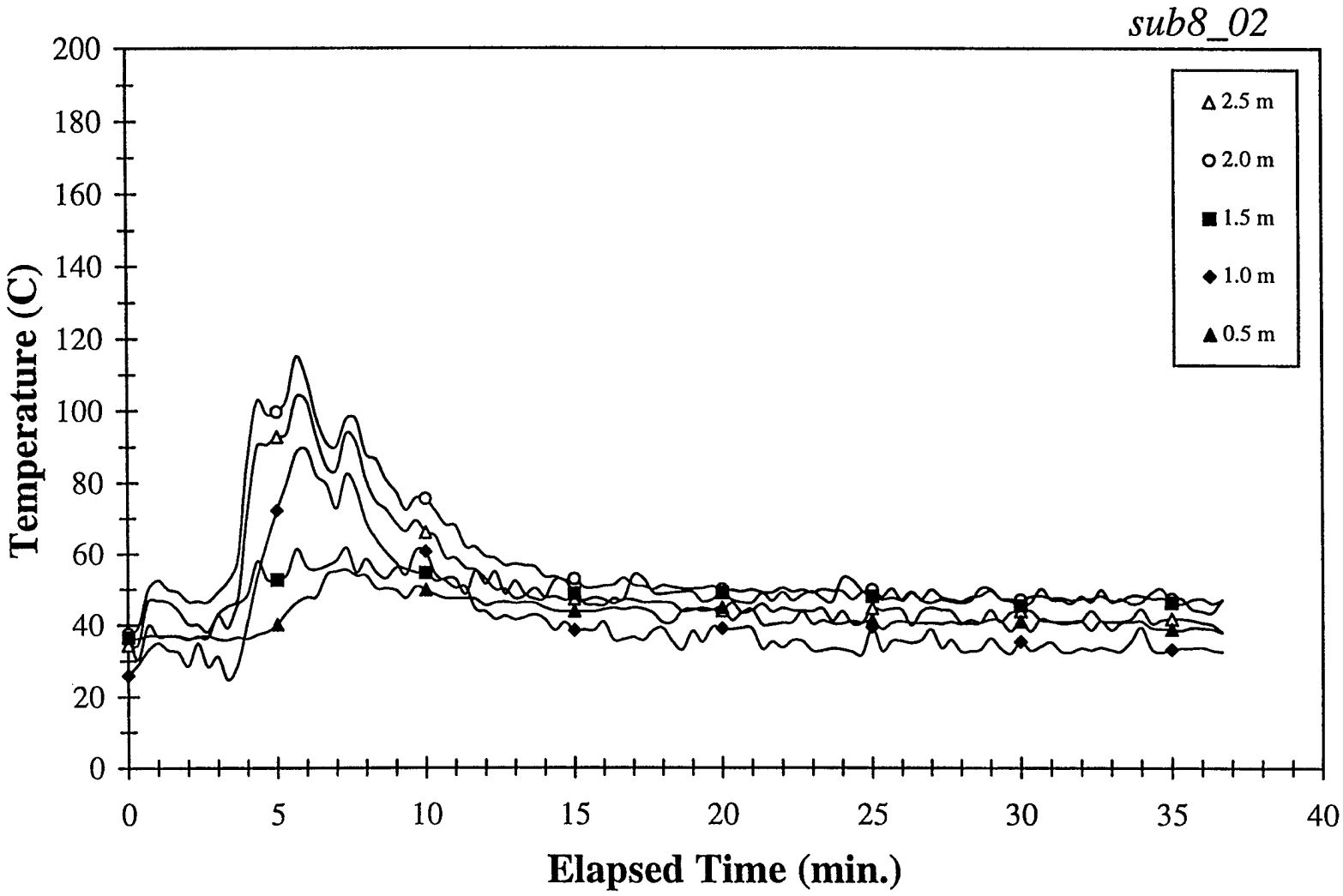

Fig. G10 – Control Room – Aft TC Tree

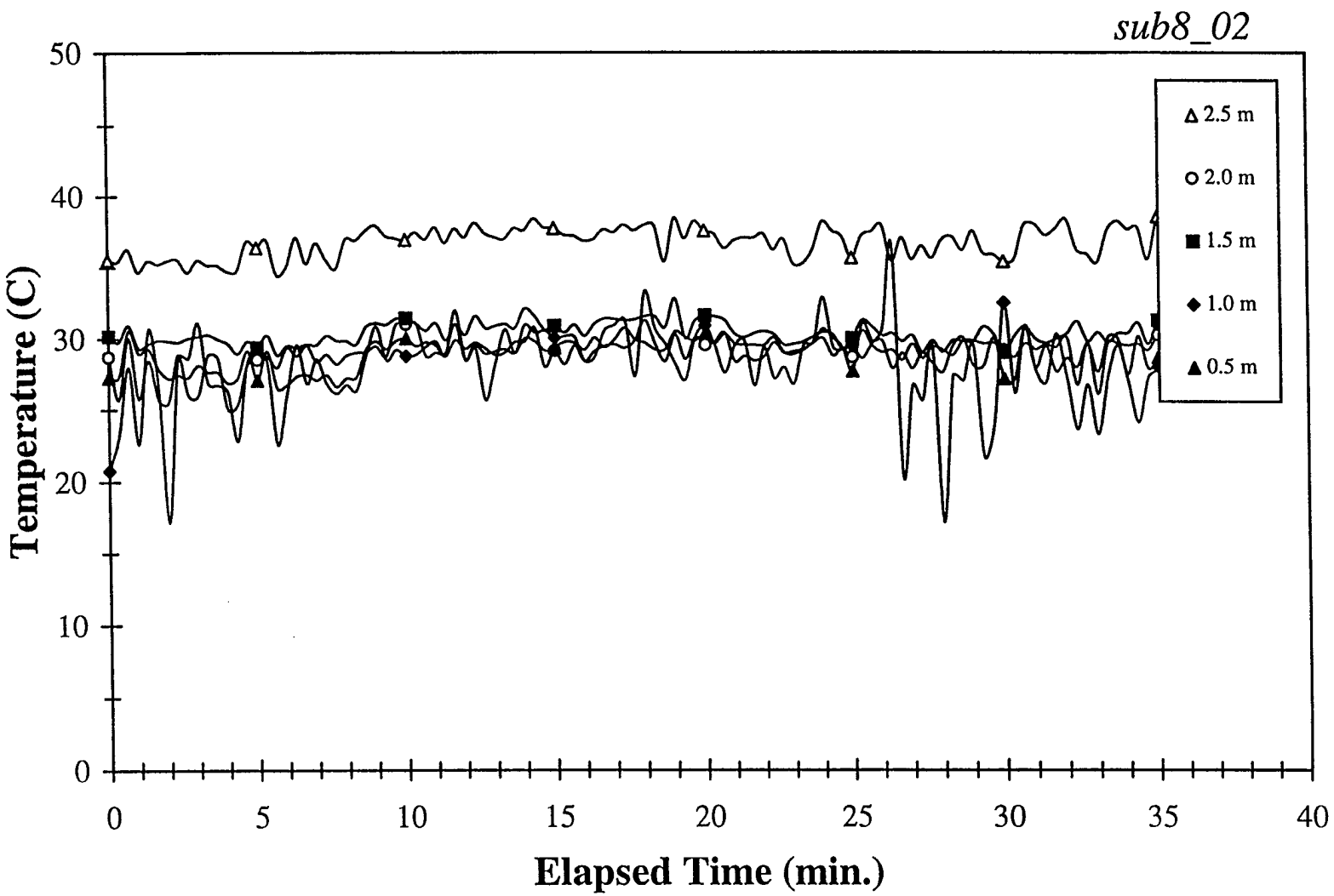

Fig. G11 – CPO/Crew Mess – Aft TC Tree

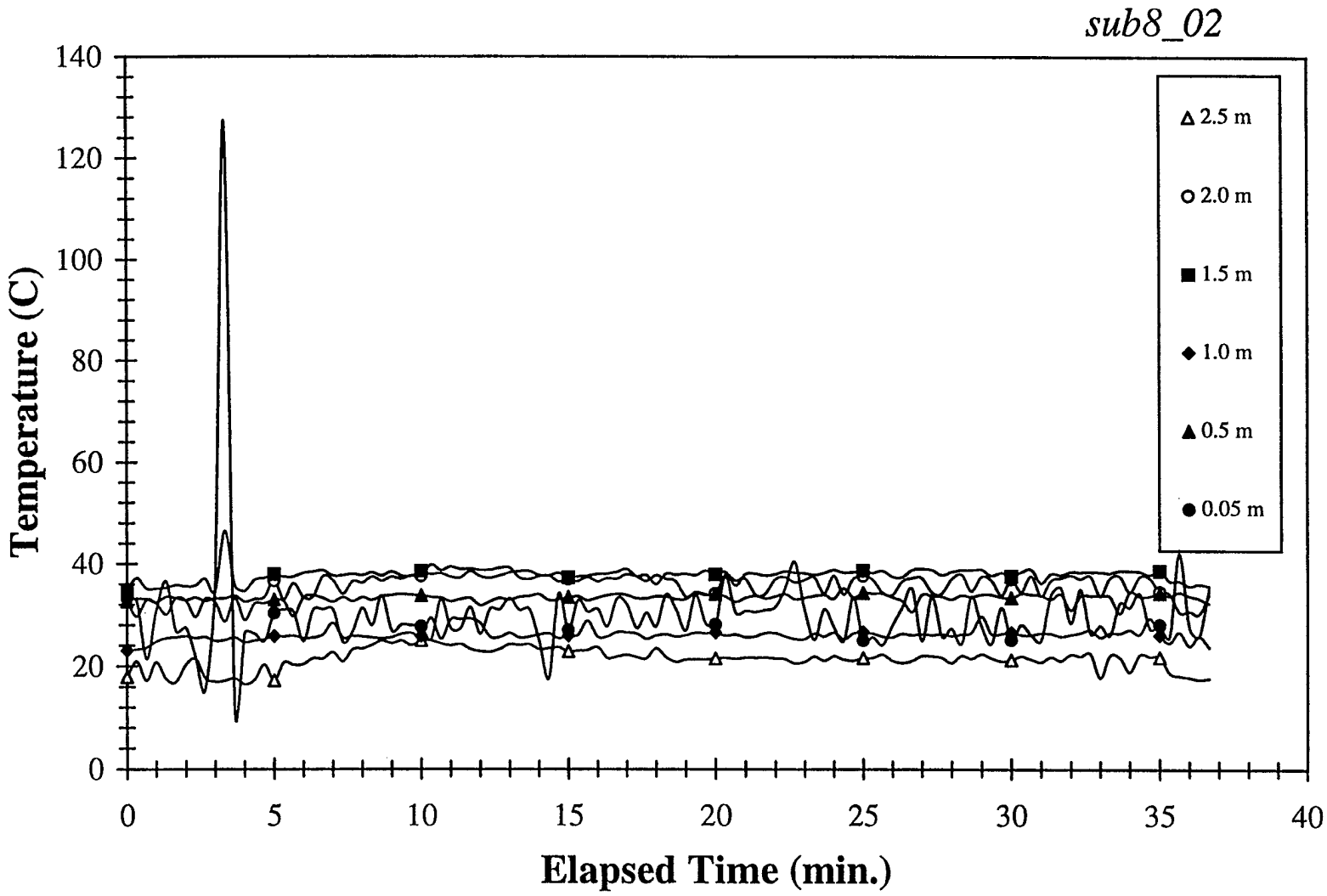

Fig. G12 – Laundry – Aft TC Tree

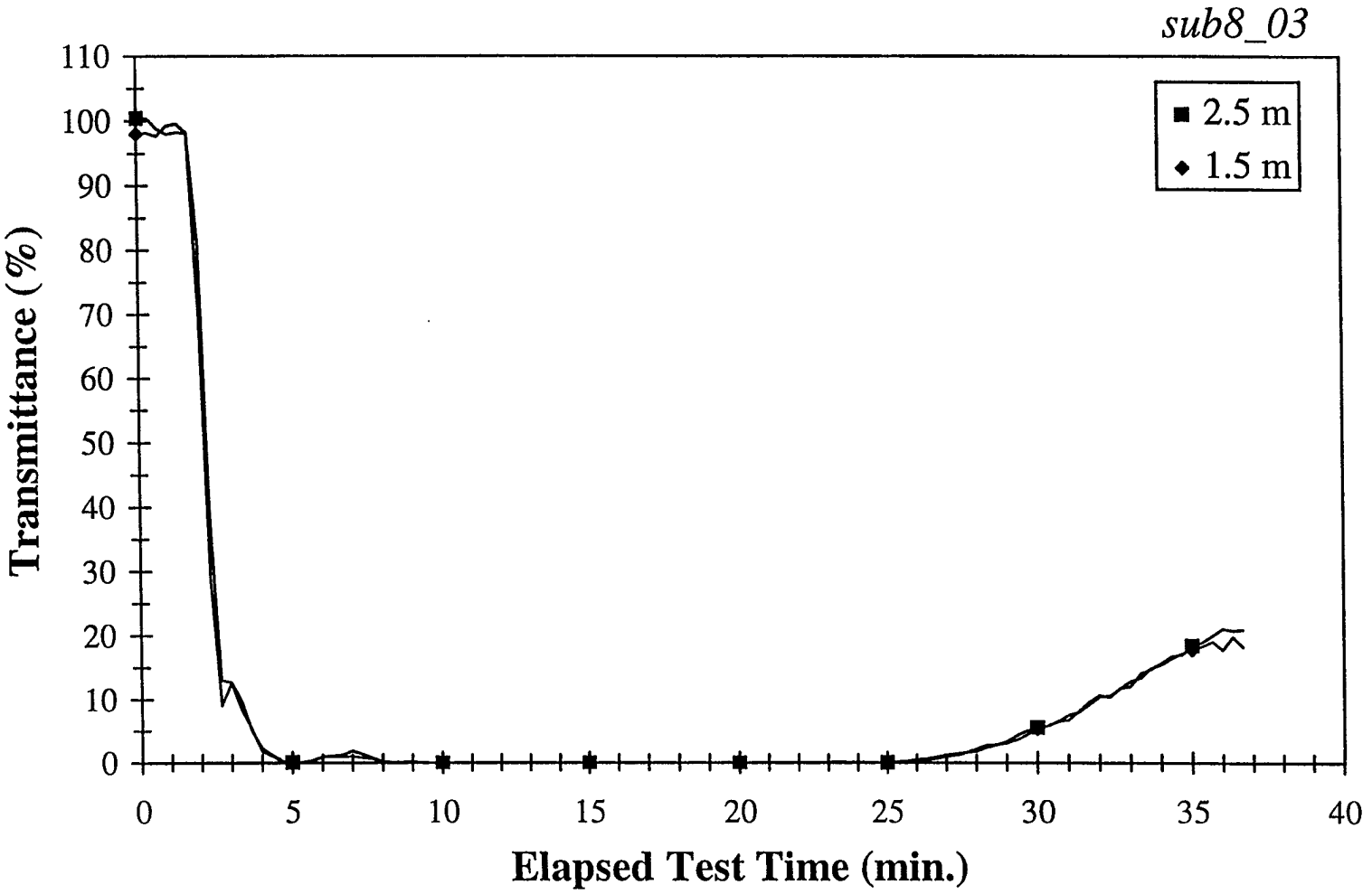

Fig. G13 – Control Room visibililty

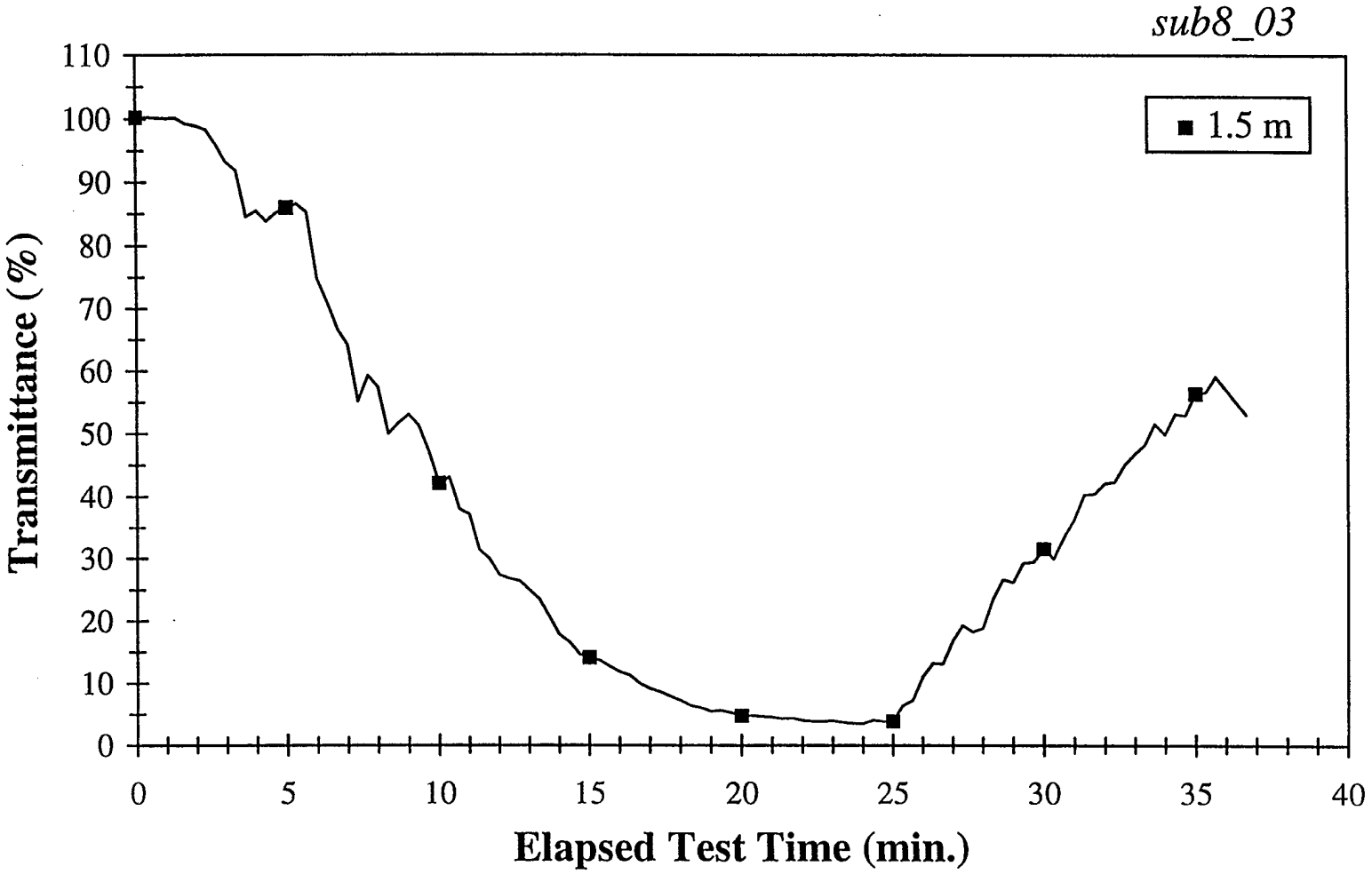

Fig. G14 - CPO/Crew Mess visibility

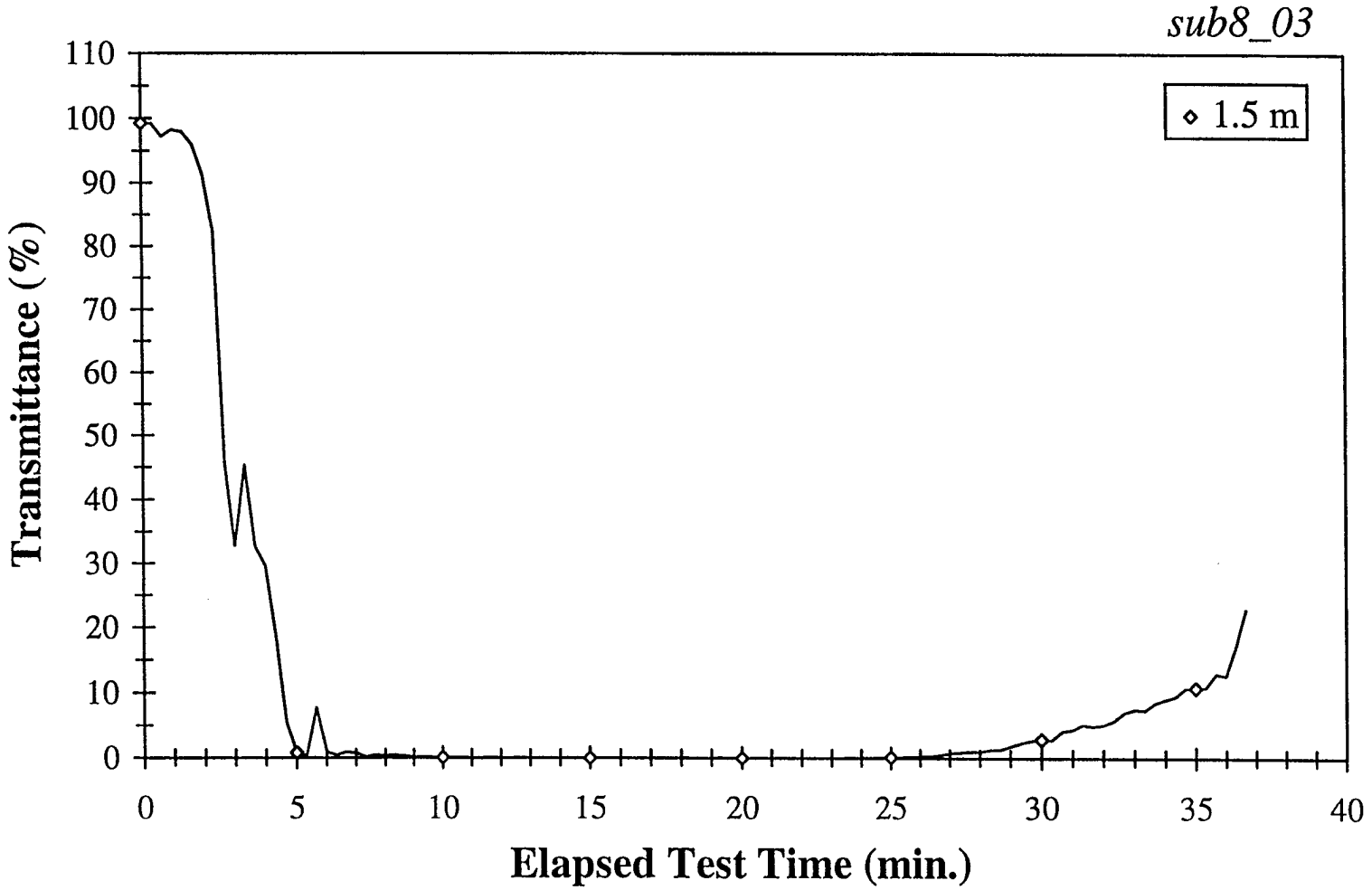

Fig. G15 – Laundry visibility

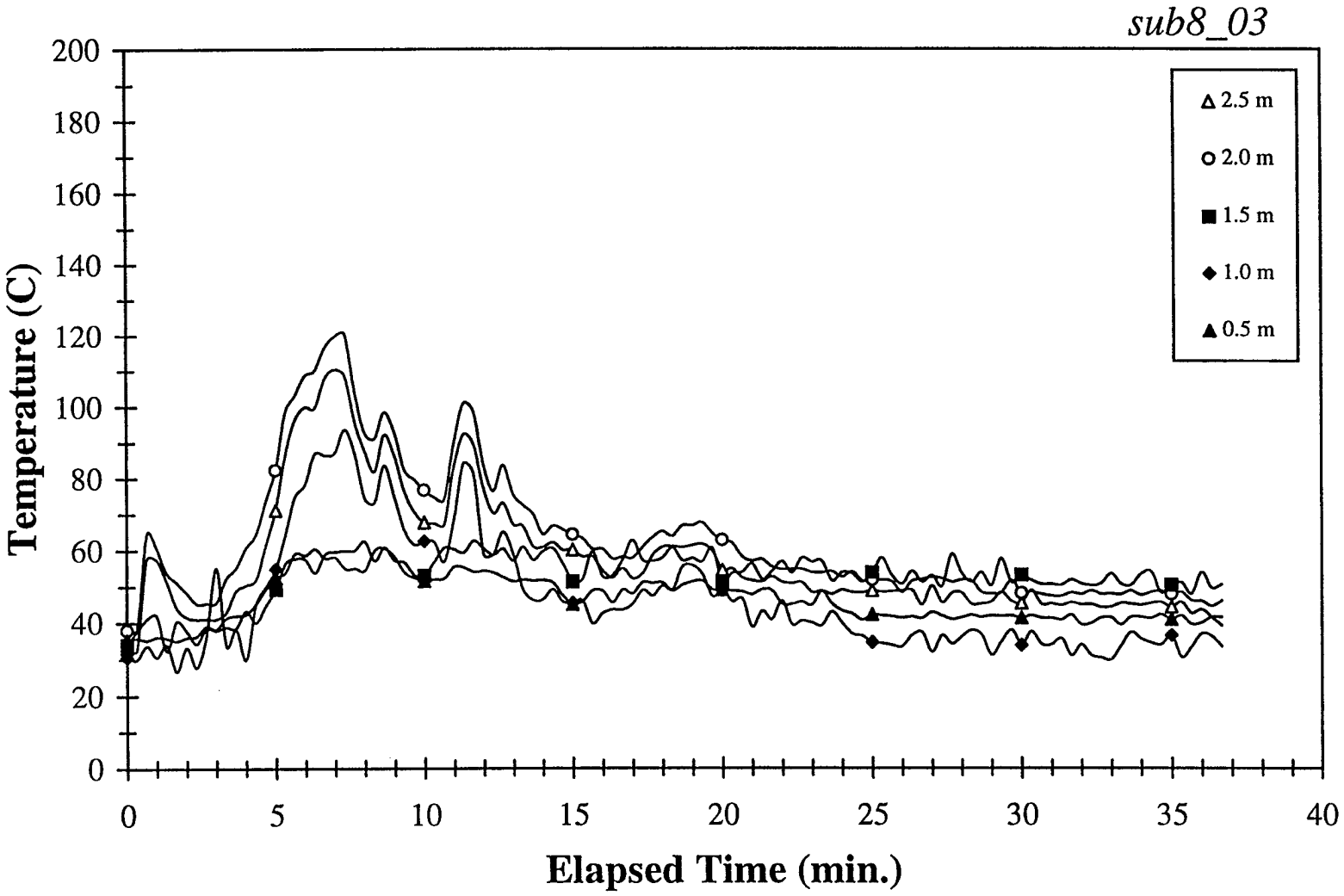

Fig. G16 – Control Room – Aft TC Tree

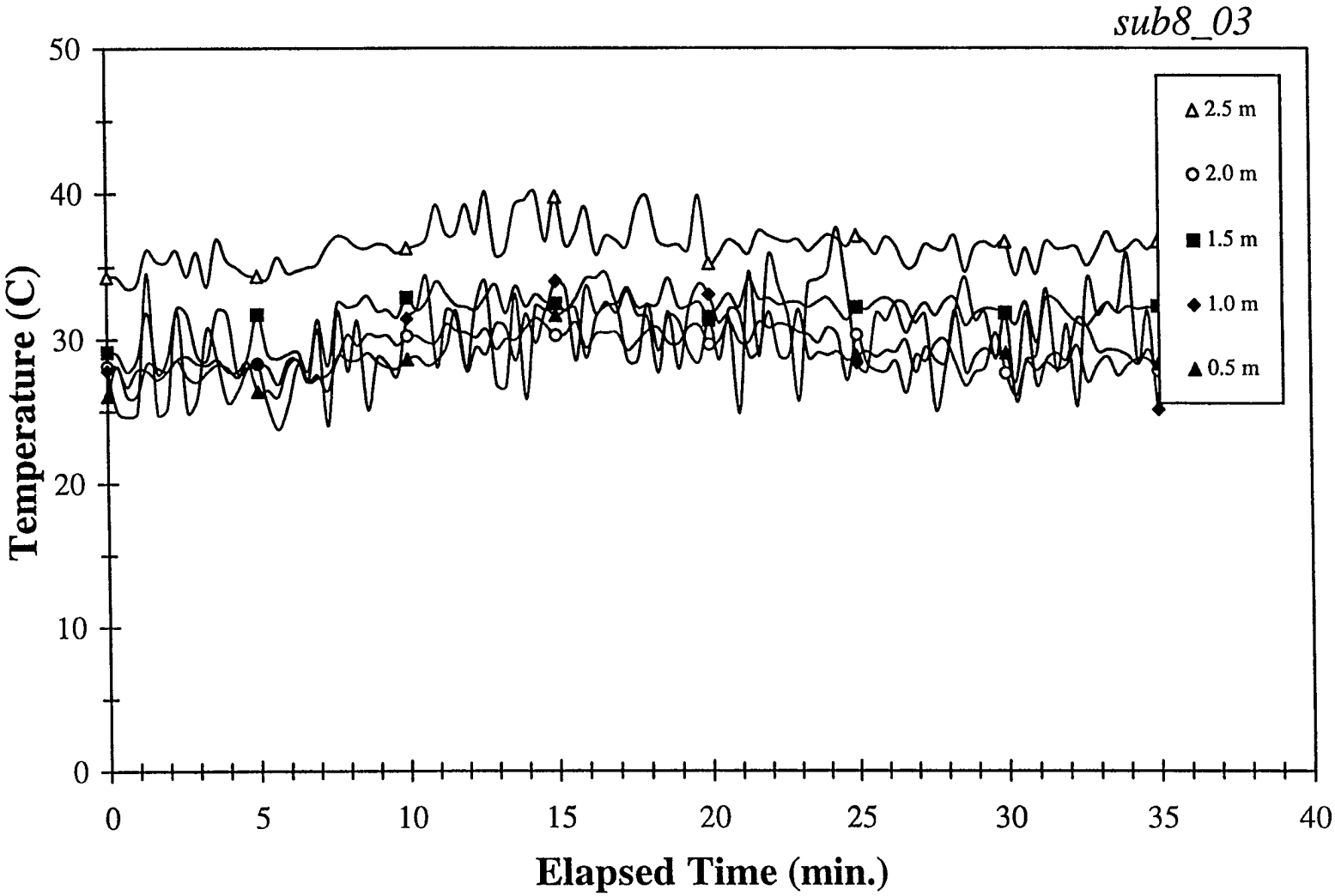

Fig. G17 – CPO/Crew Mess – Aft TC Tree

Tree 2-93

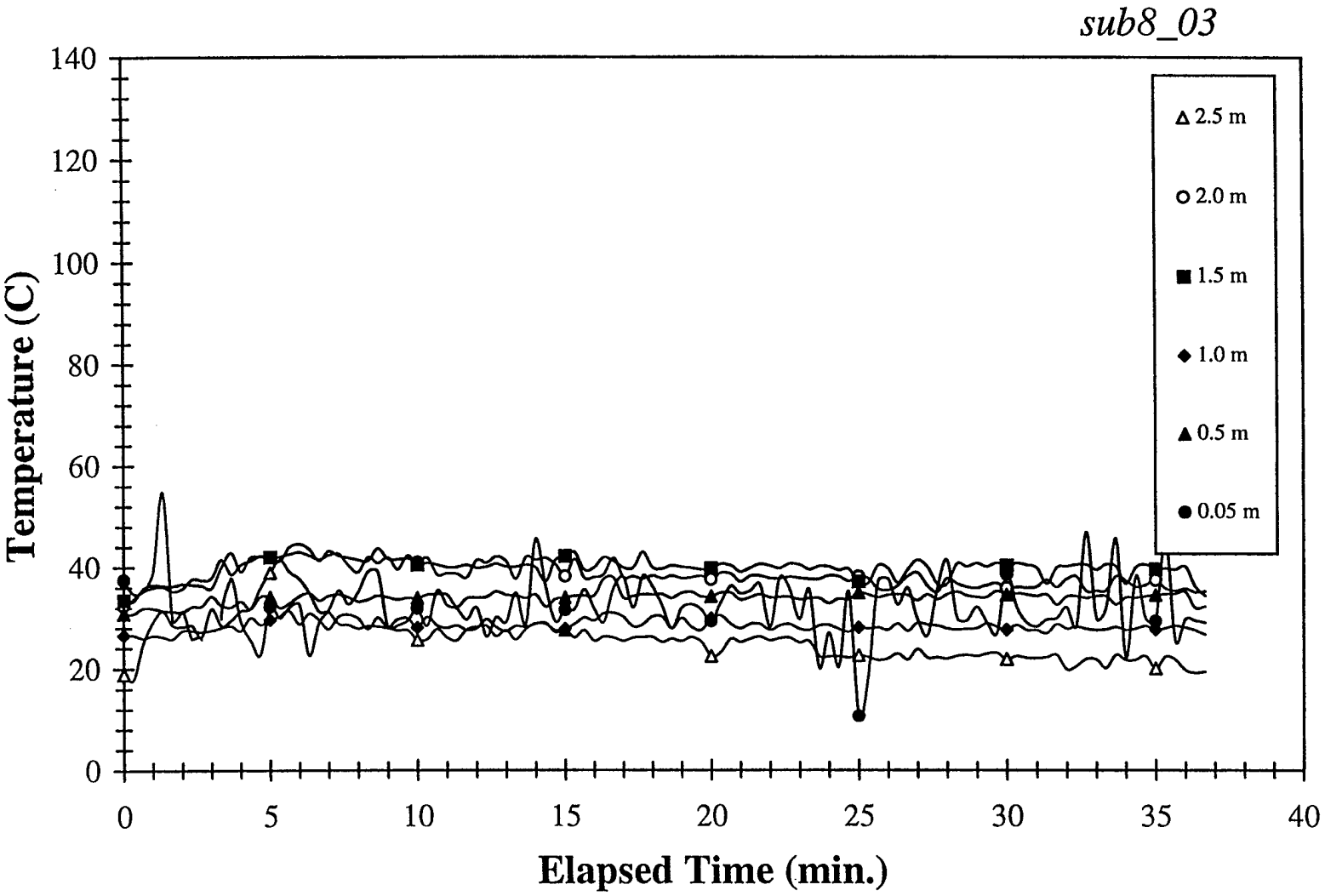

Fig. G18 – Laundry – Aft TC Tree

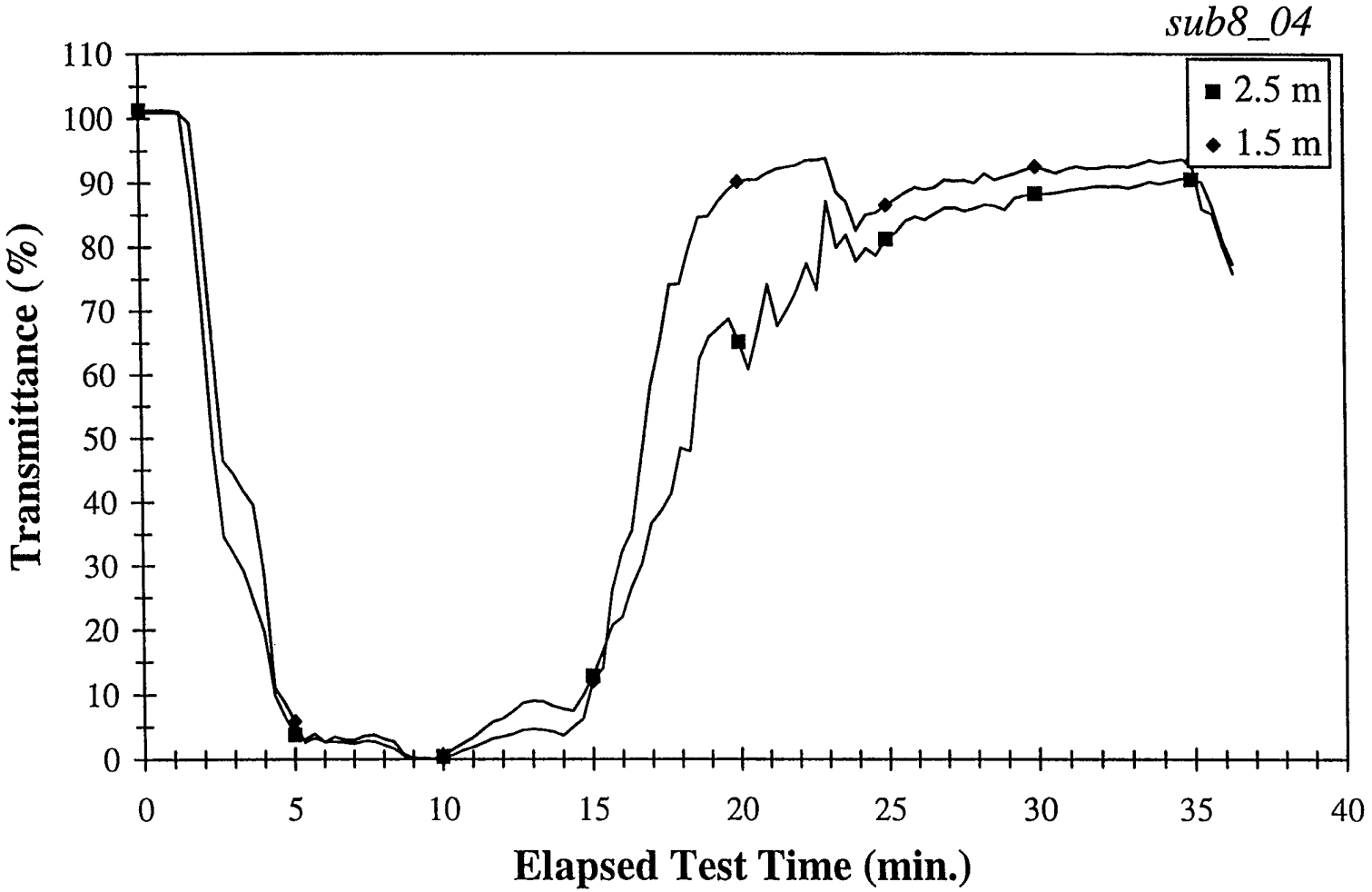

Fig. G19 – Control Room visibility

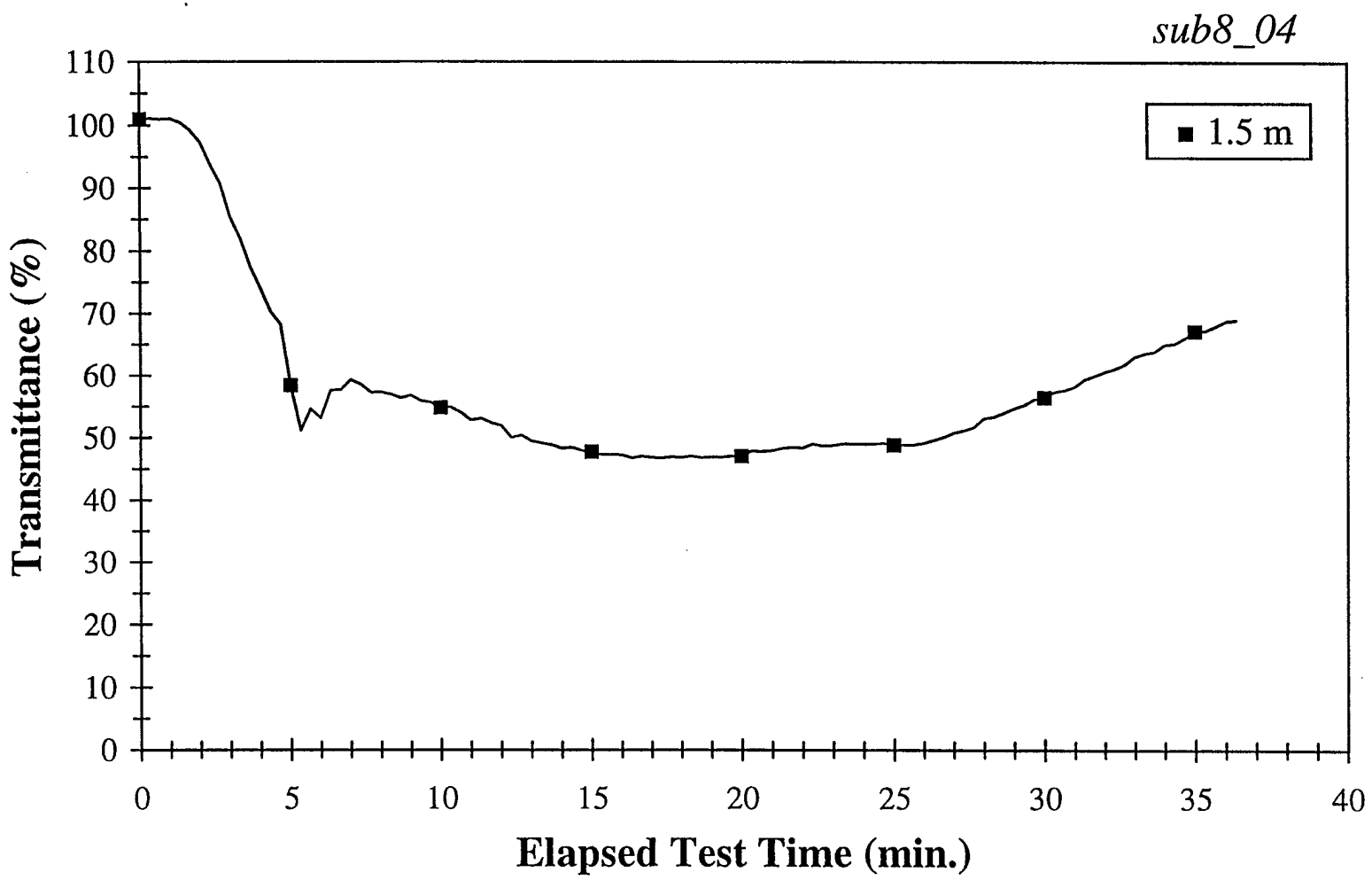

Fig. G20 - CPO/Crew Mess visibility

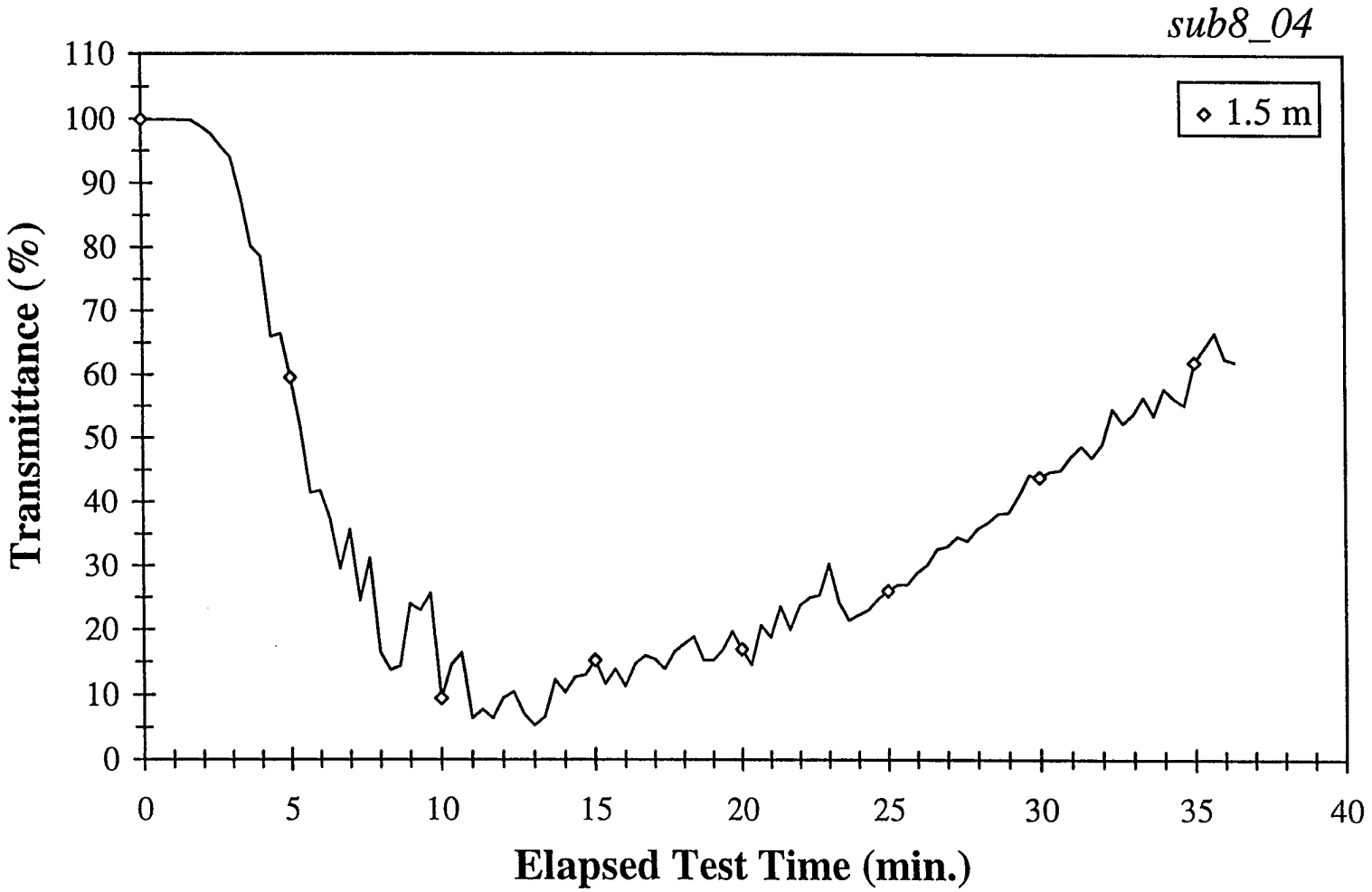

Fig. G21 – Laundry visibility

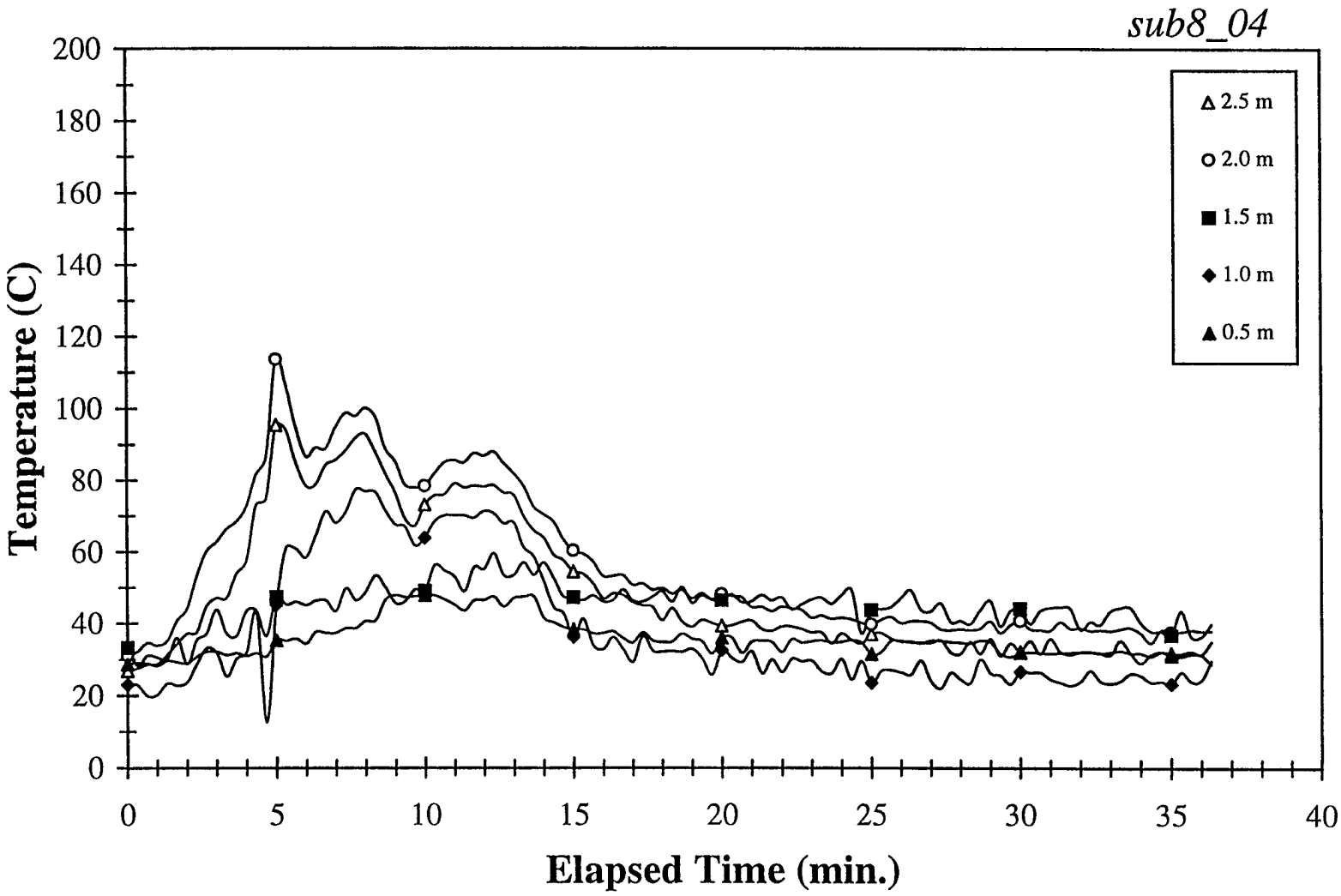

Fig. G22 - Control Room - Aft TC Tree

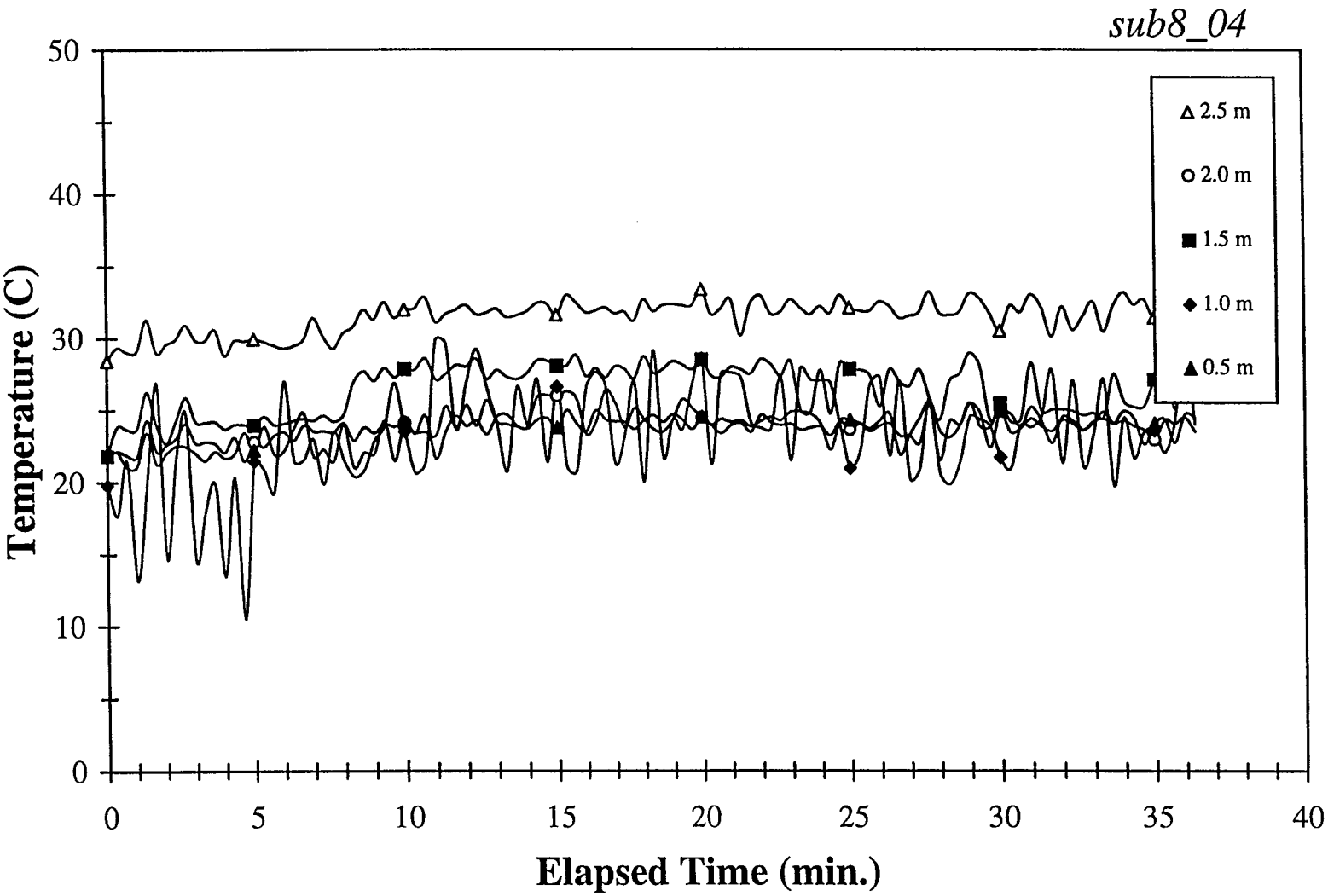

Fig. G23 – CPO/Crew Mess – Aft TC Tree

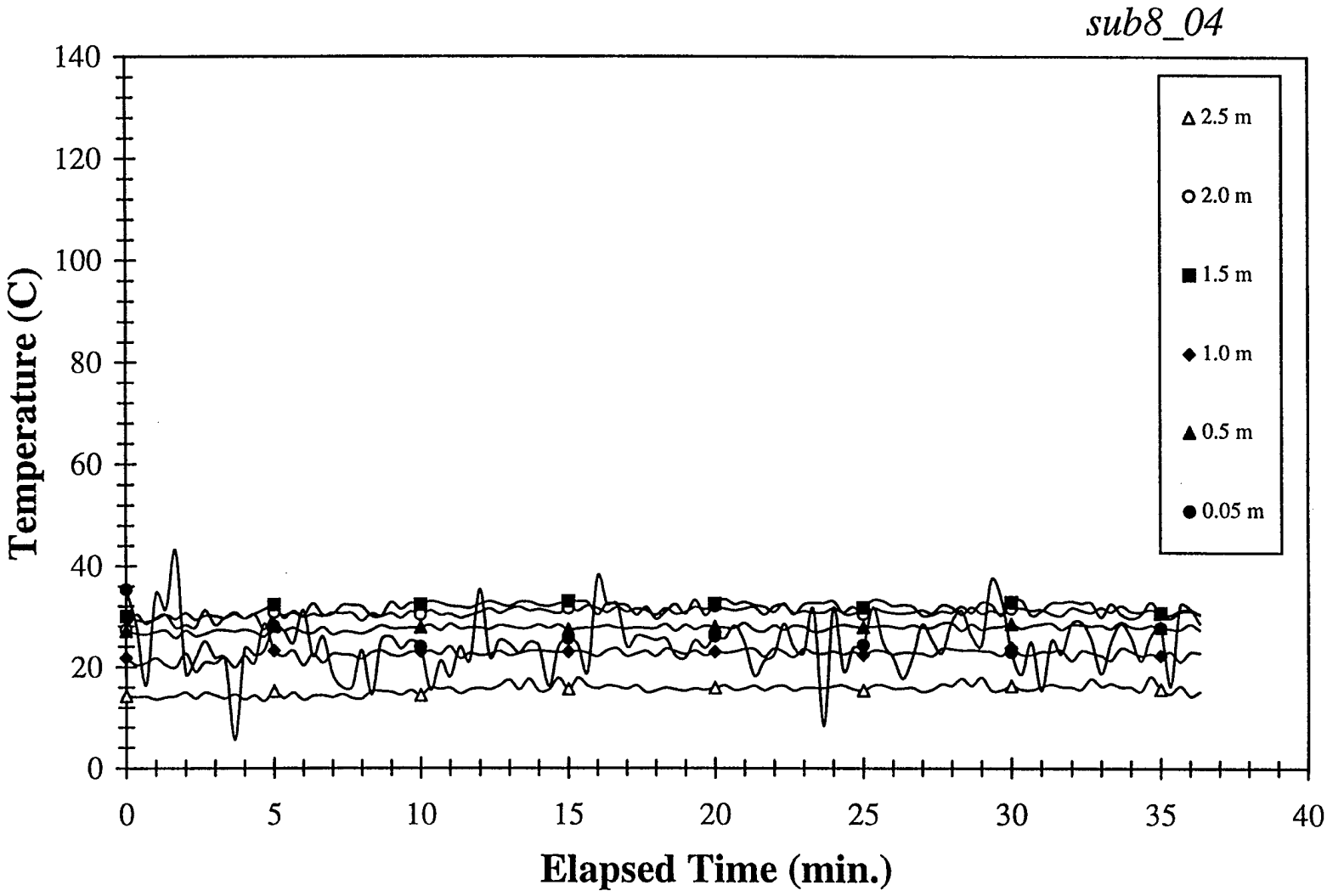

Fig. G24 – Laundry – Aft TC Tree

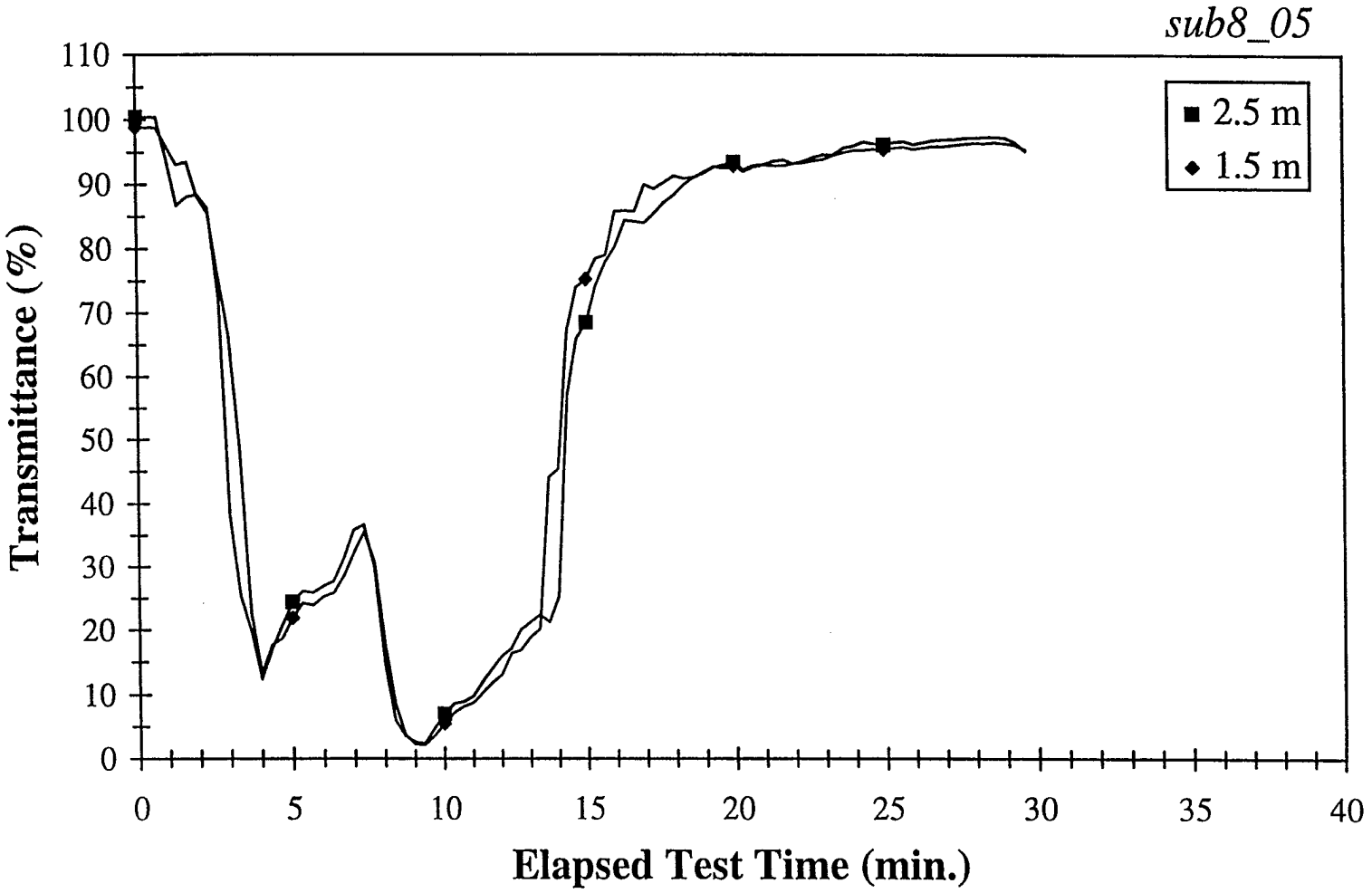

Fig. G25 – Control Room visibility

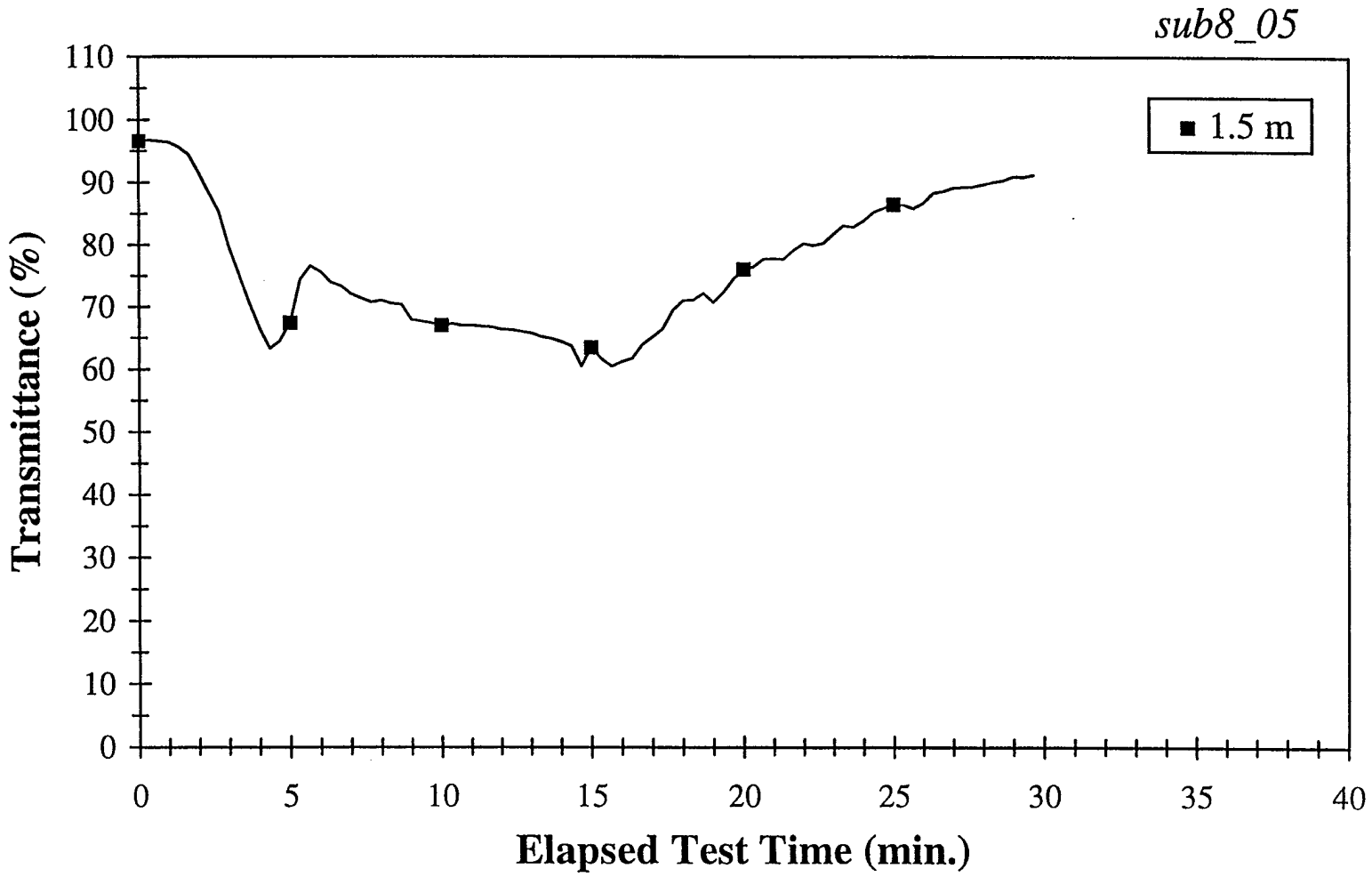

Fig. G26 – CPO/Crew Mess visibility

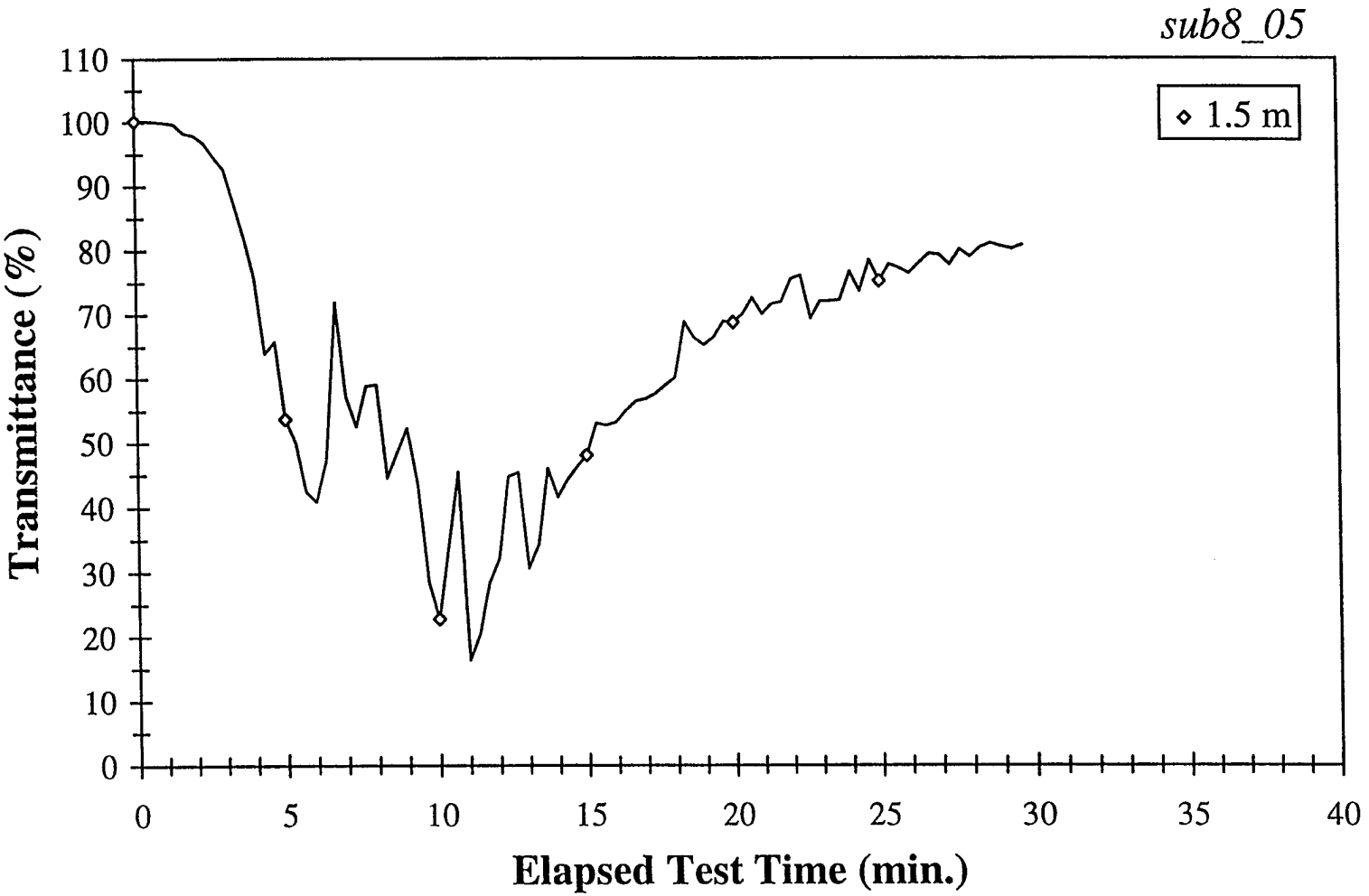

Fig. G27 – Laundry visibility

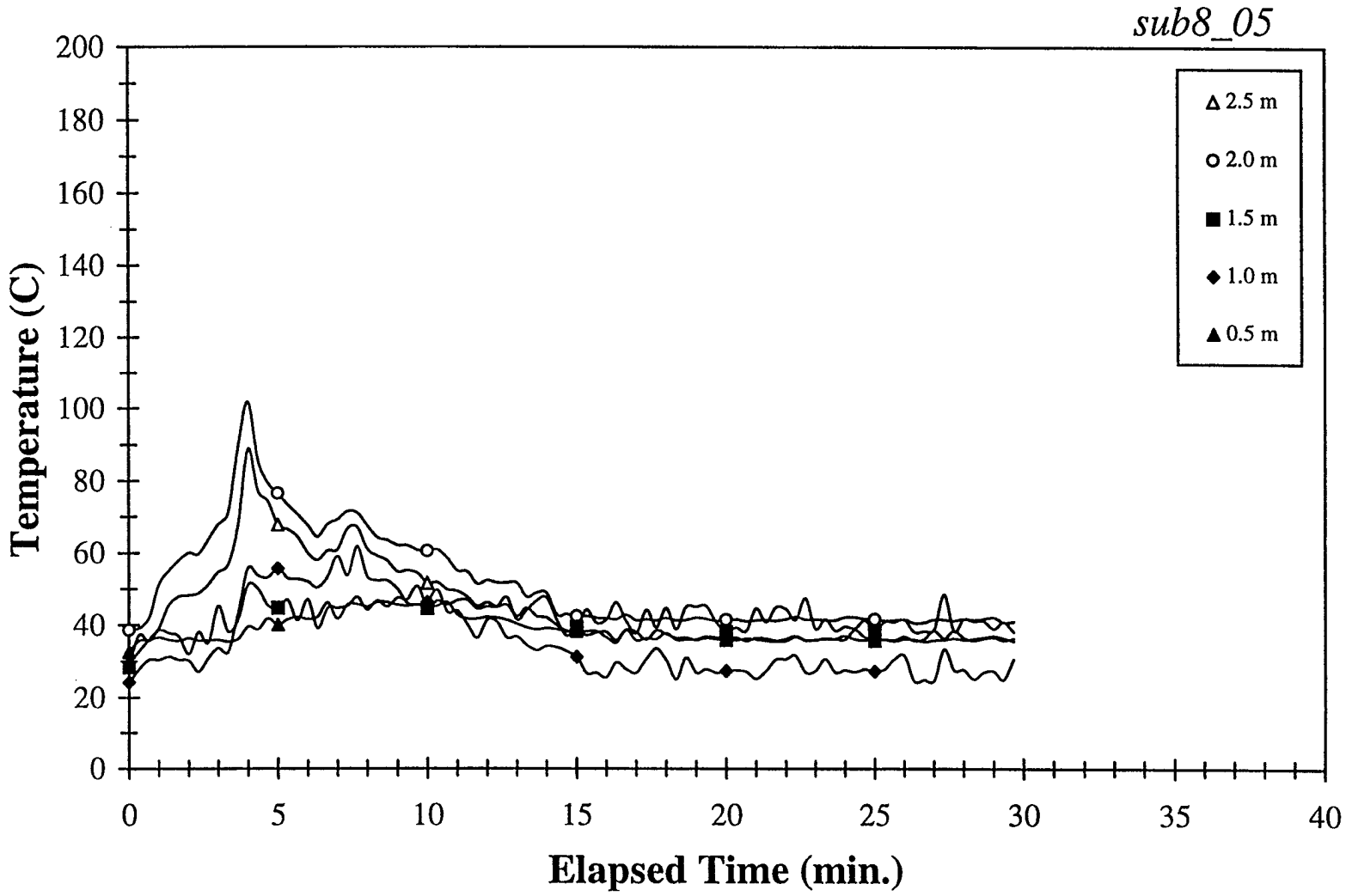

Fig. G28 – Control Room – Aft TC Tree

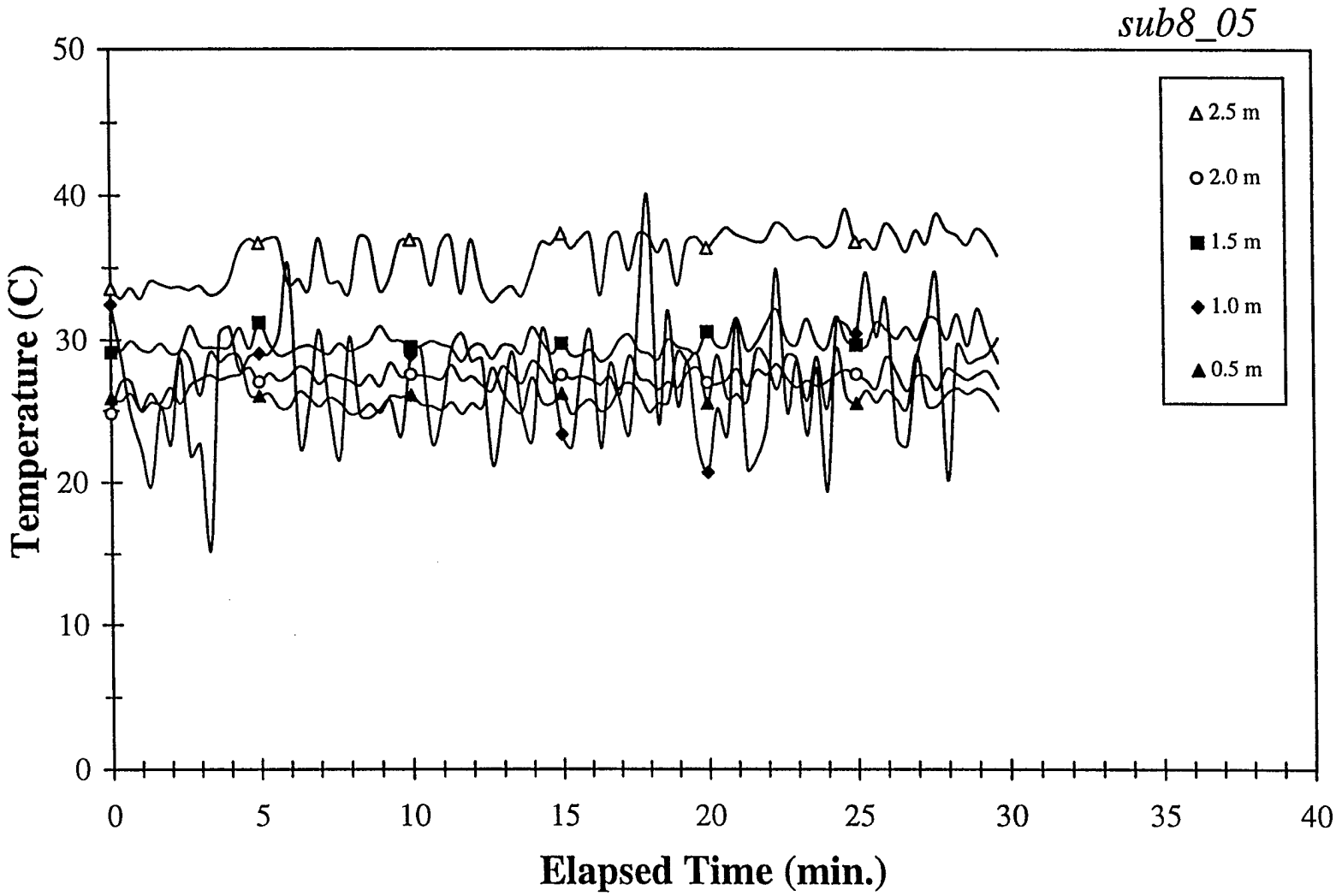

Fig. G29 – CPO/Crew Mess – Aft TC Tree

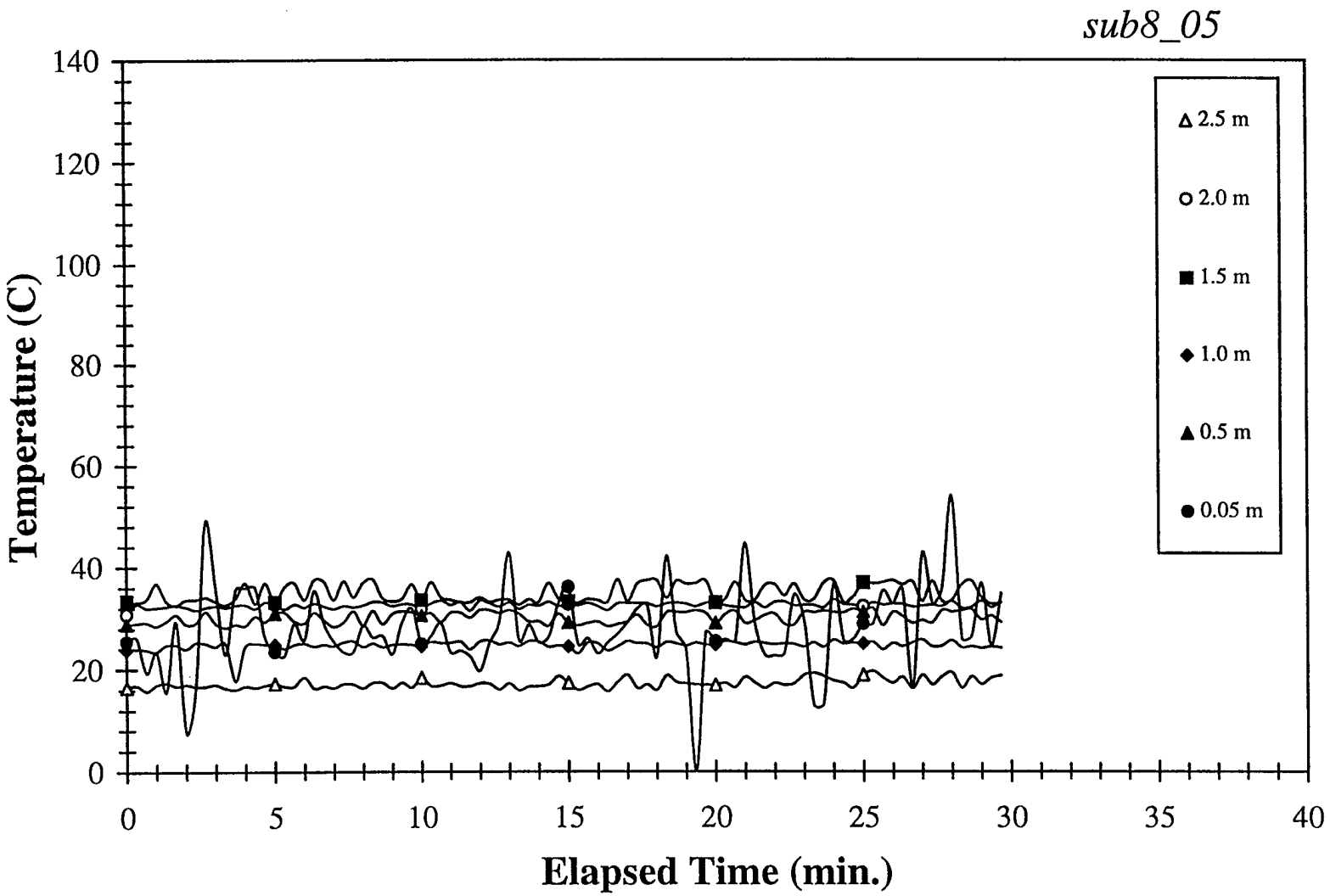

Fig. G30 – Laundry – Aft TC Tree

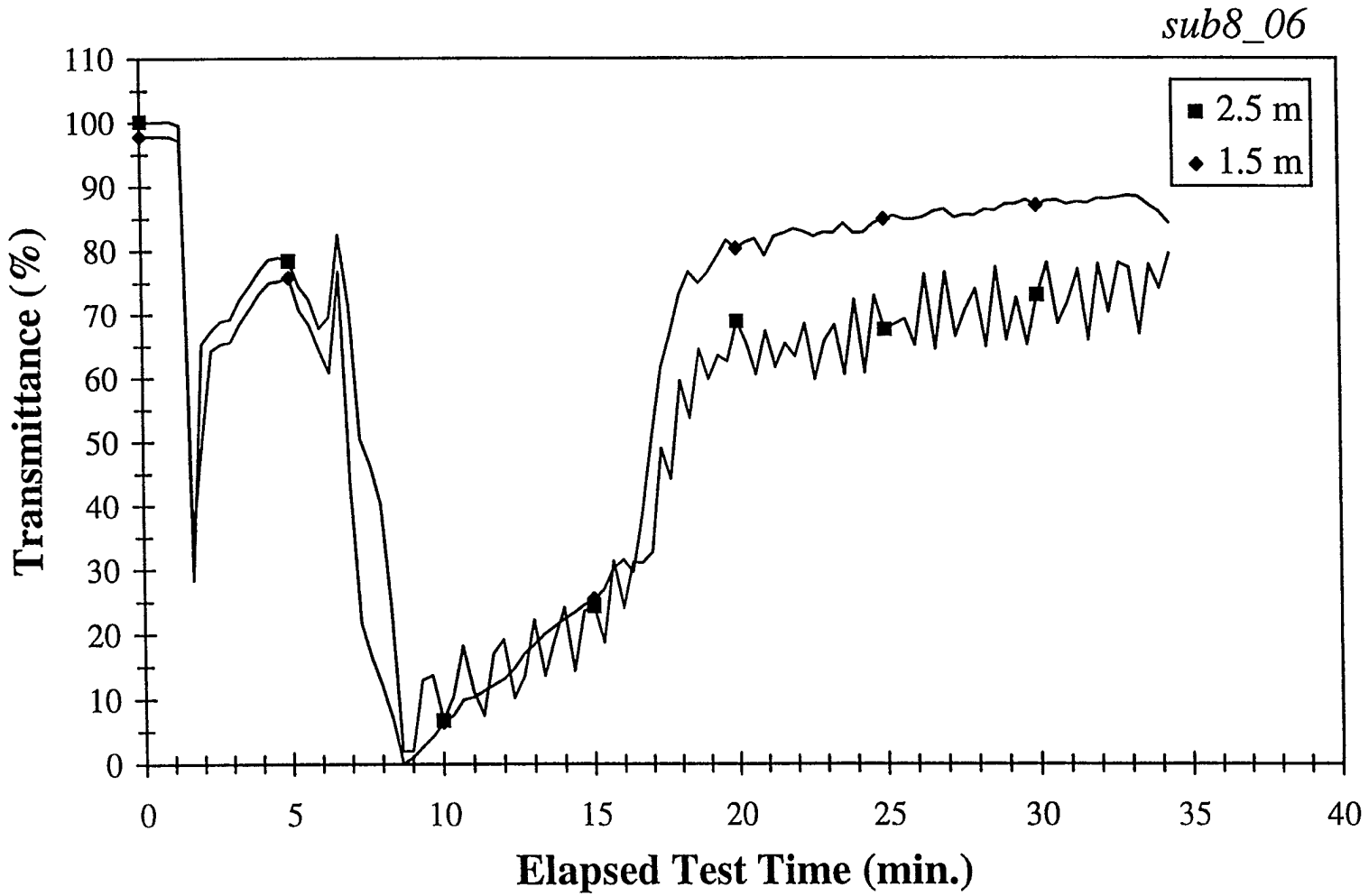

Fig. G31 – Control Room visibility

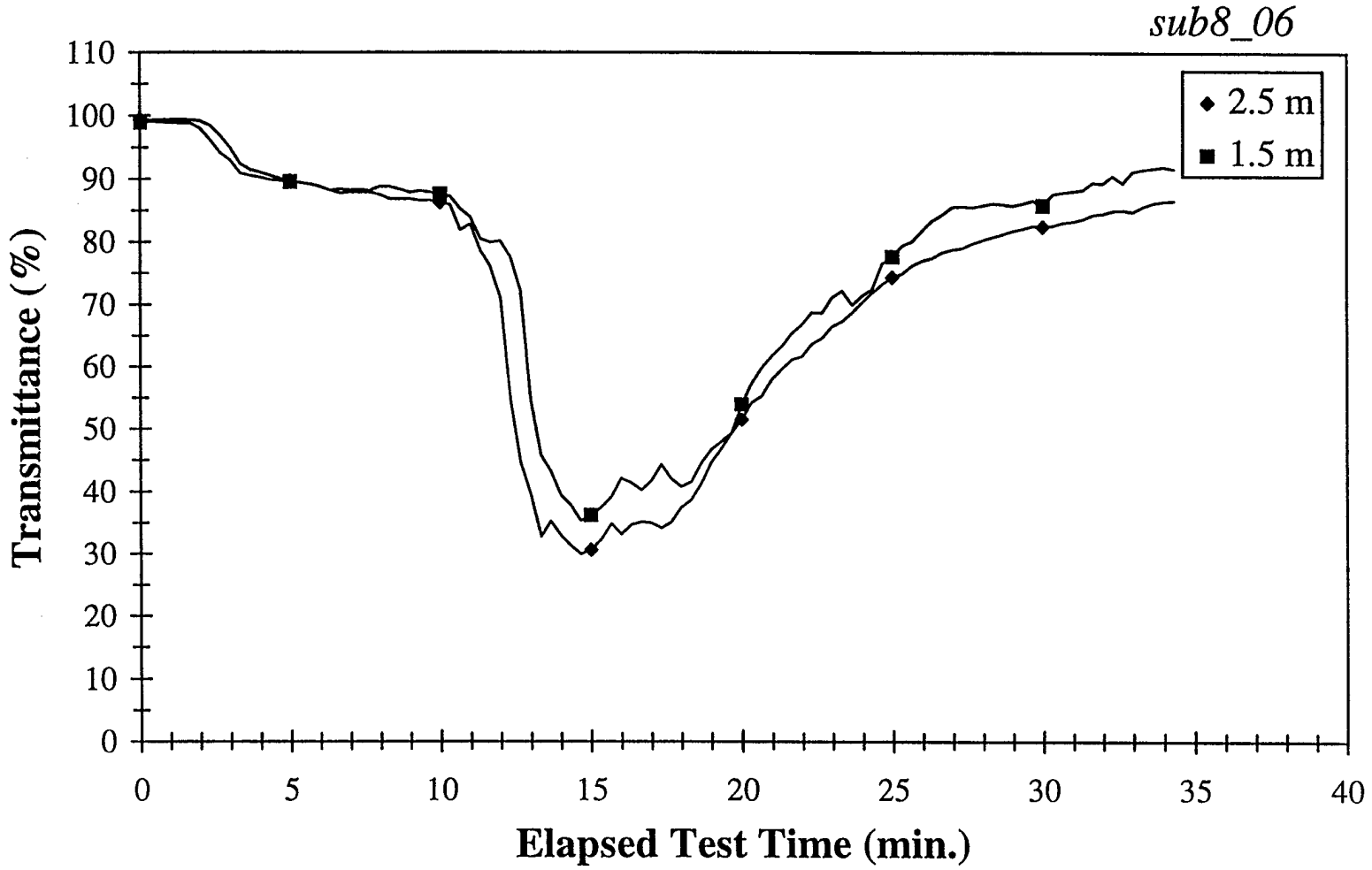

Fig. G32 – CPO/Crew Mess visibility

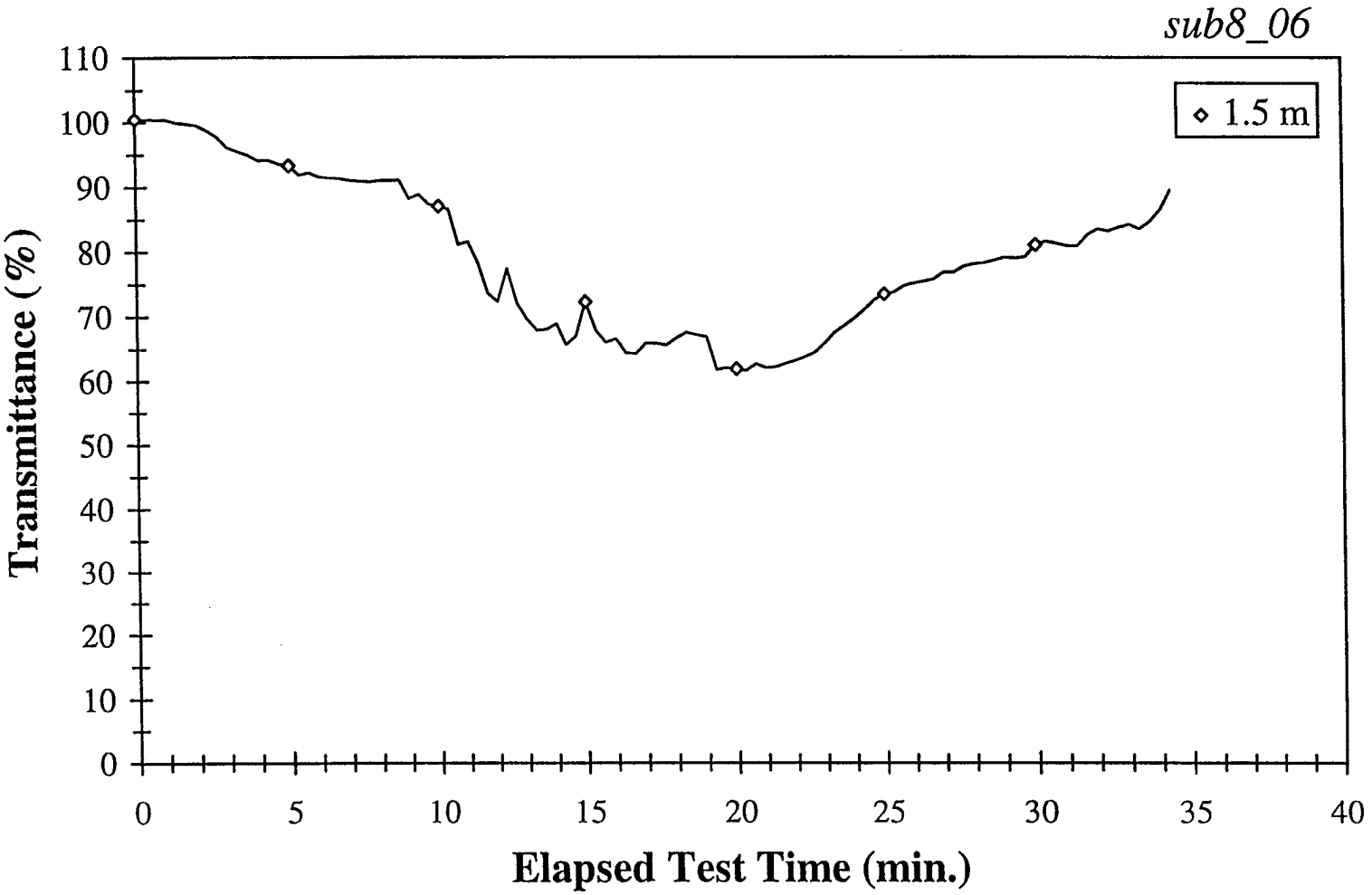

Fig. G33 – Laundry visibility

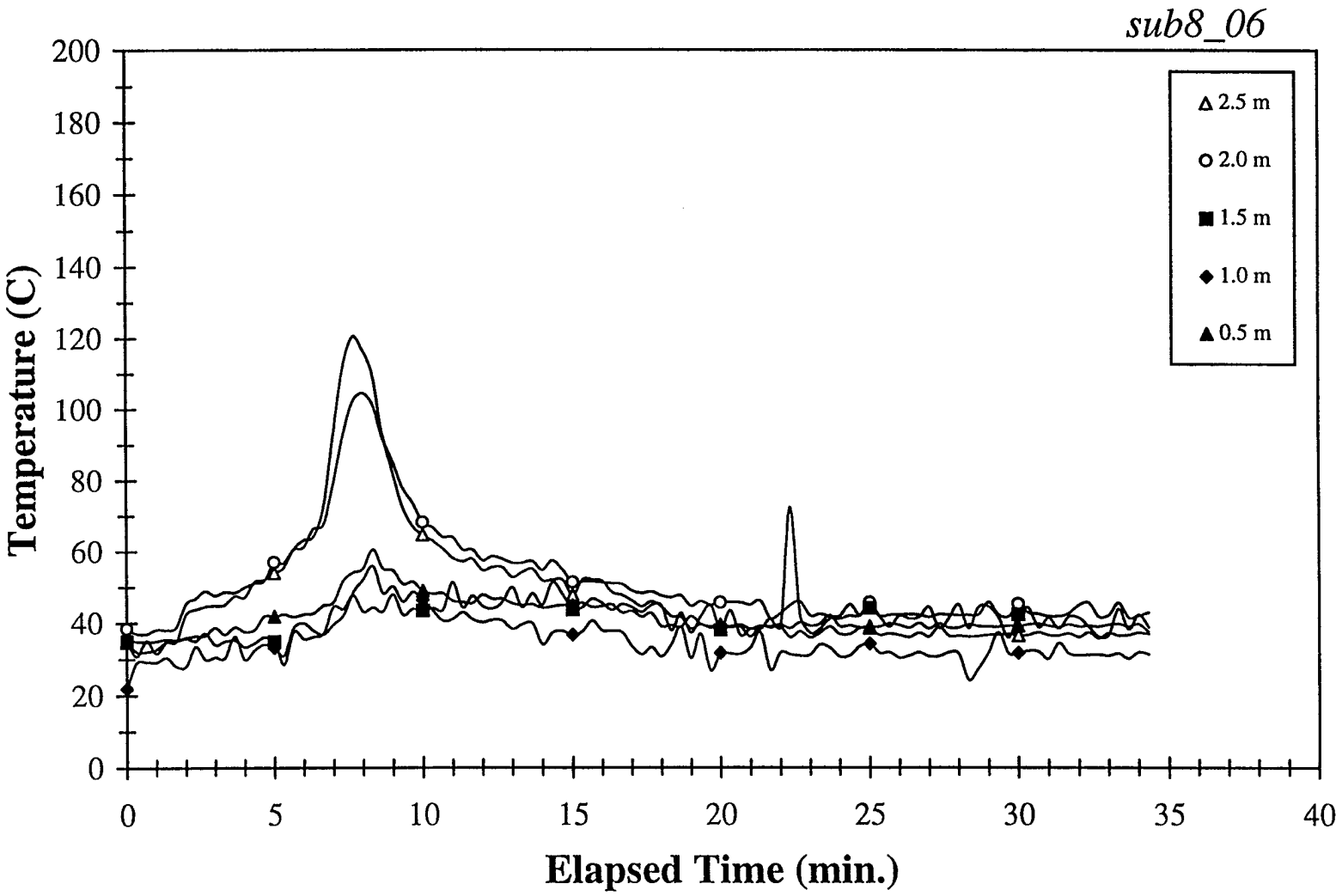

Fig. G34 – Control Room – Aft TC Tree

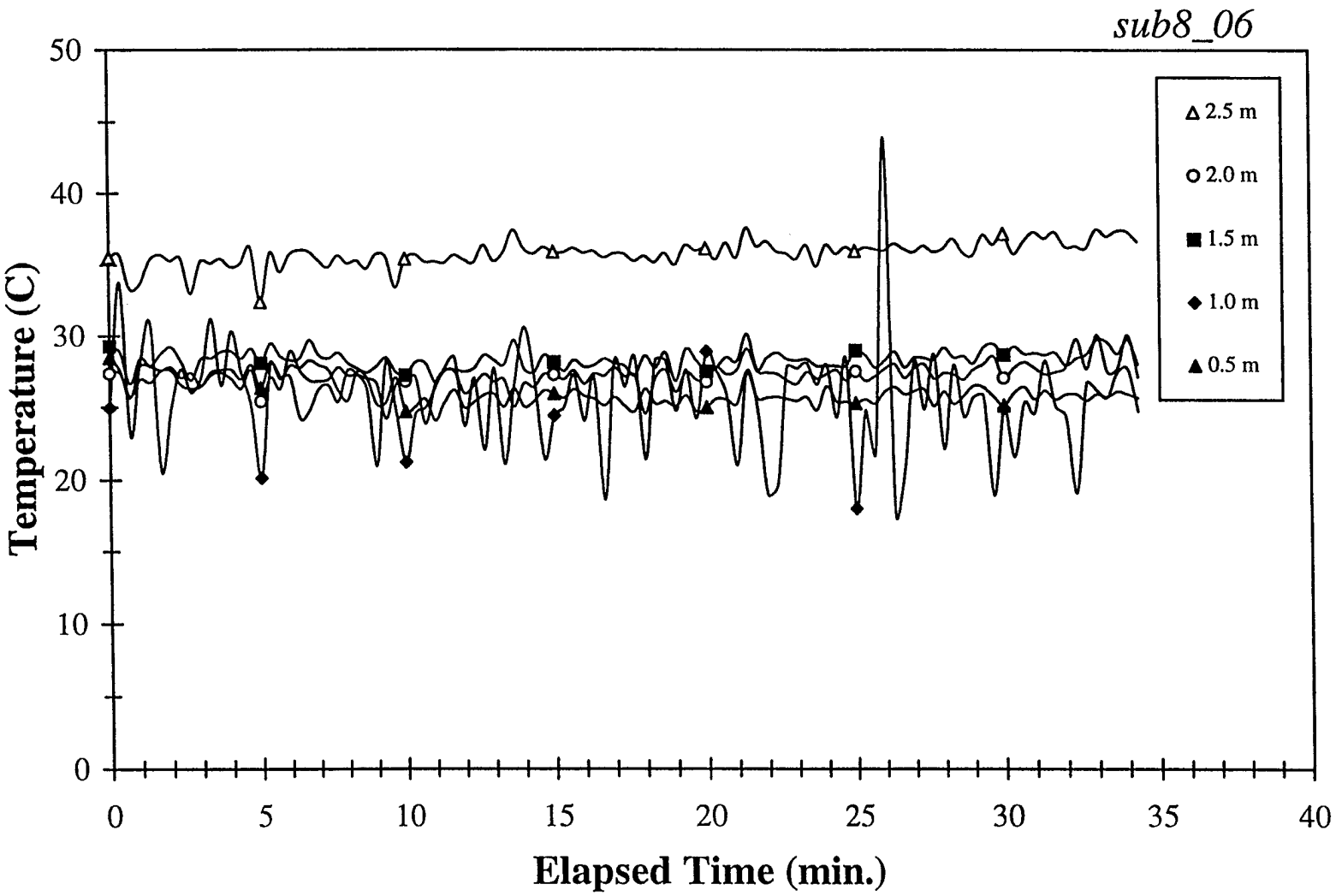

Fig. G35 – CPO/Crew Mess – Aft TC Tree

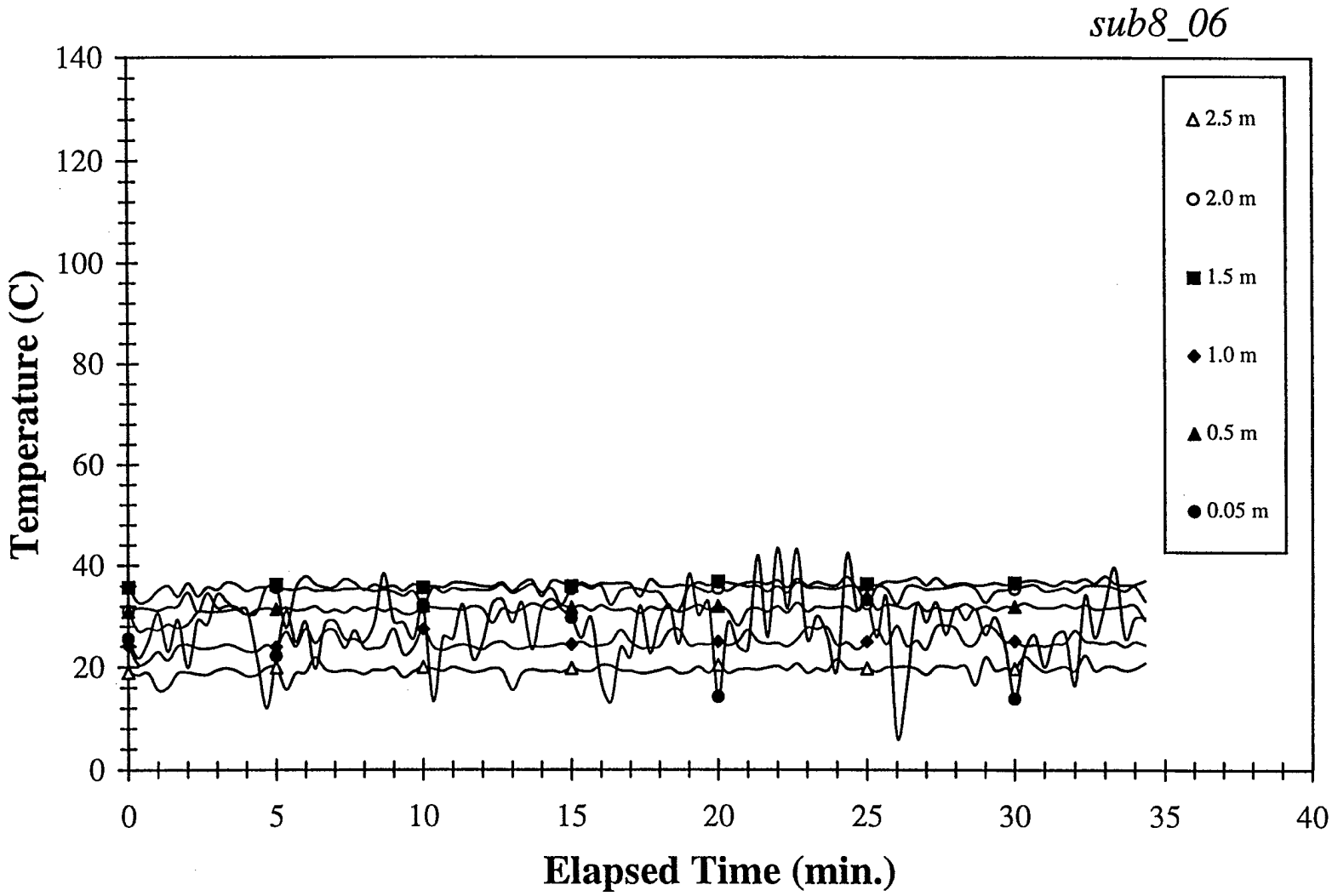

Fig. G36 – Laundry – Aft TC Tree

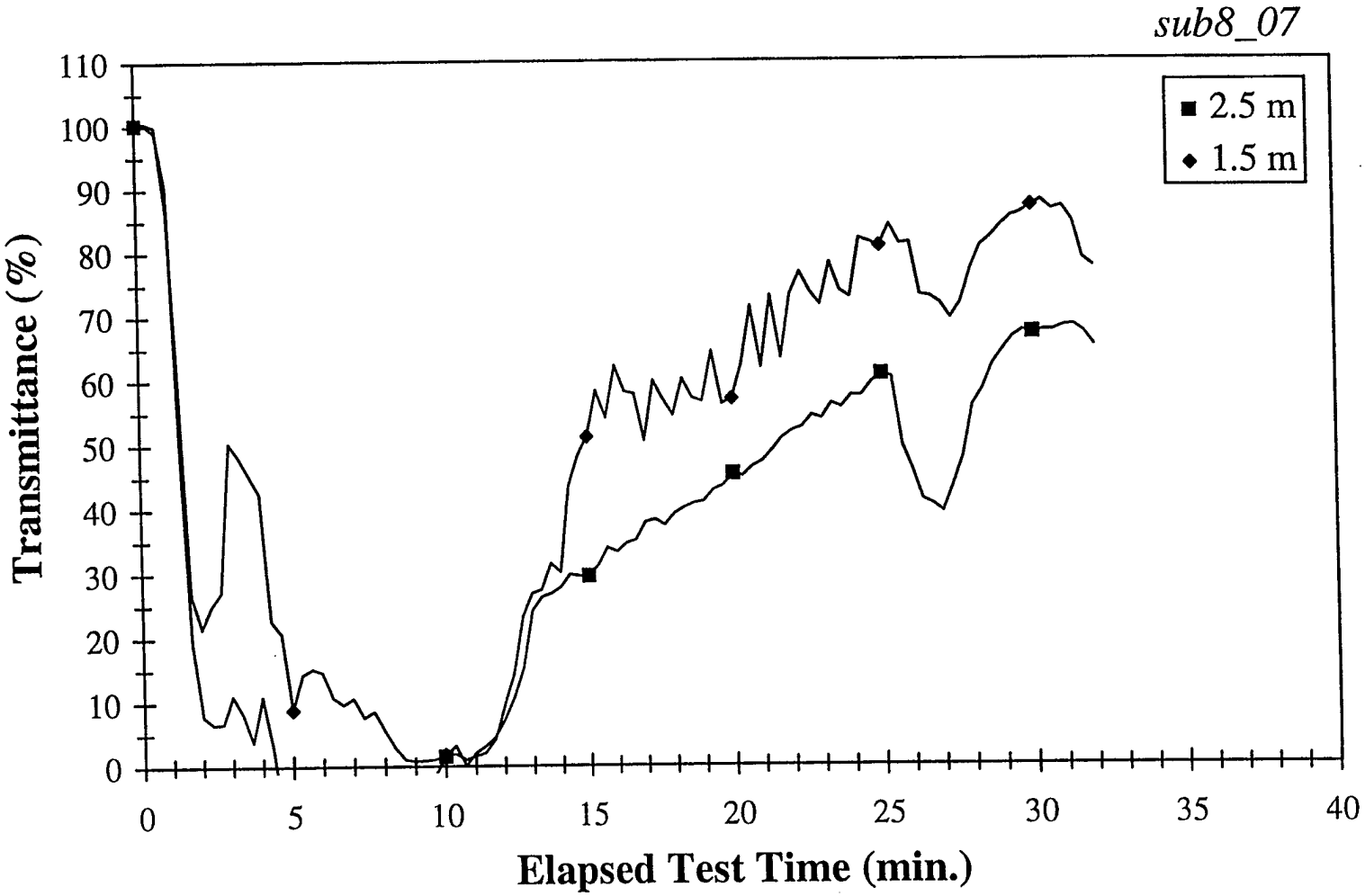

Fig. G37 - Control Room visibility

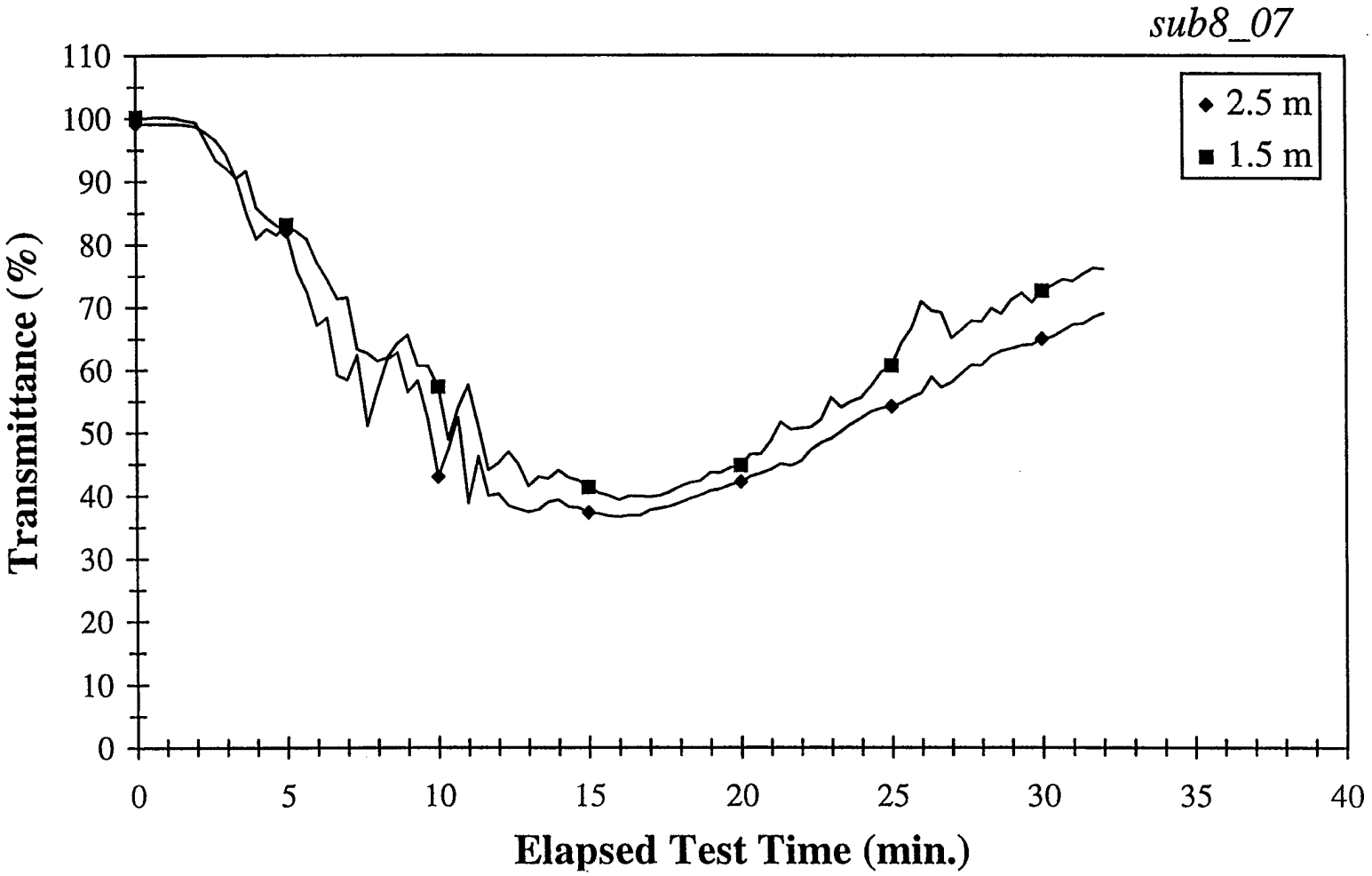

Fig. G38 – CPO/Crew Mess visibility

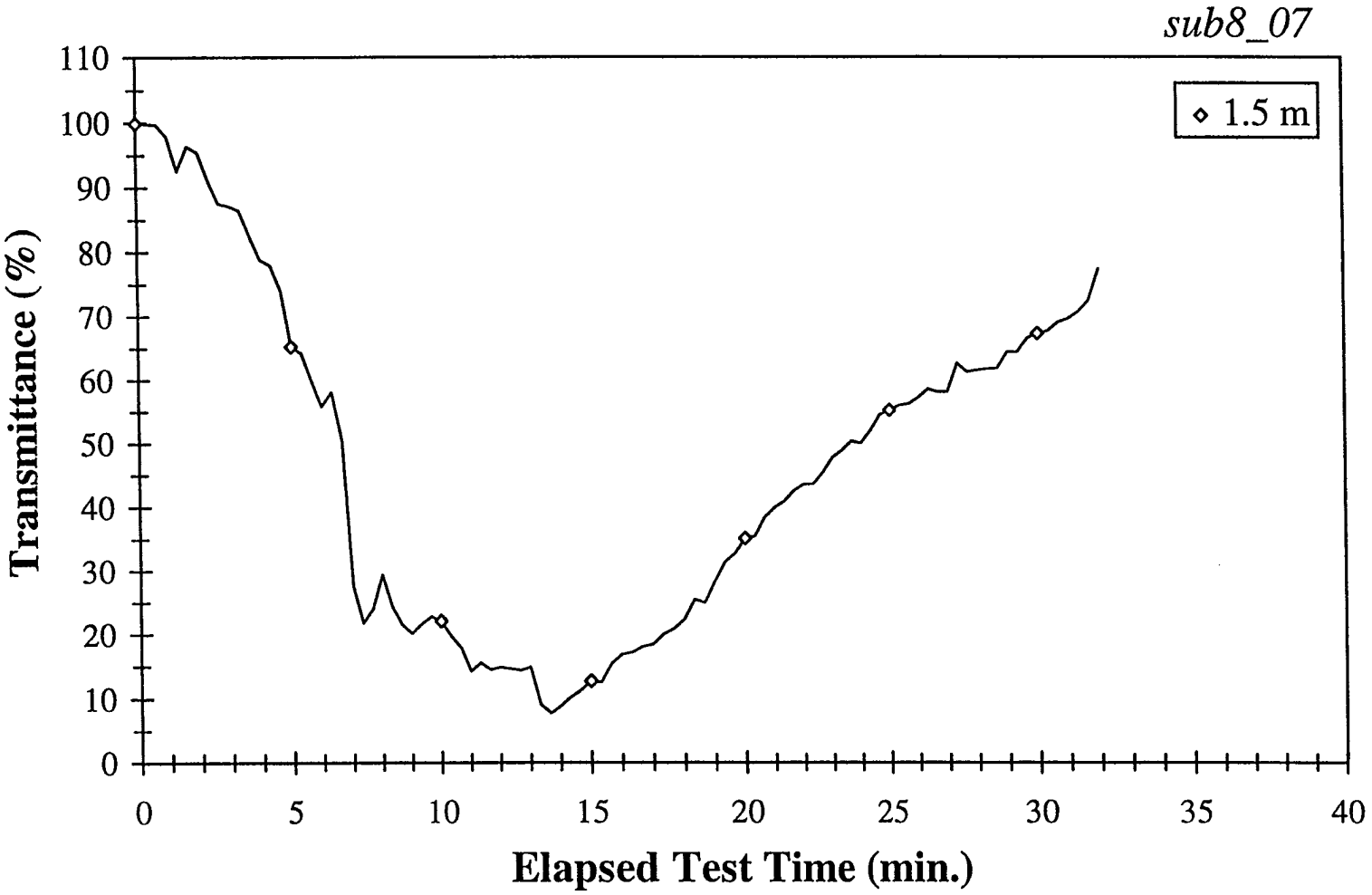

Fig. G39 – Laundry visibility

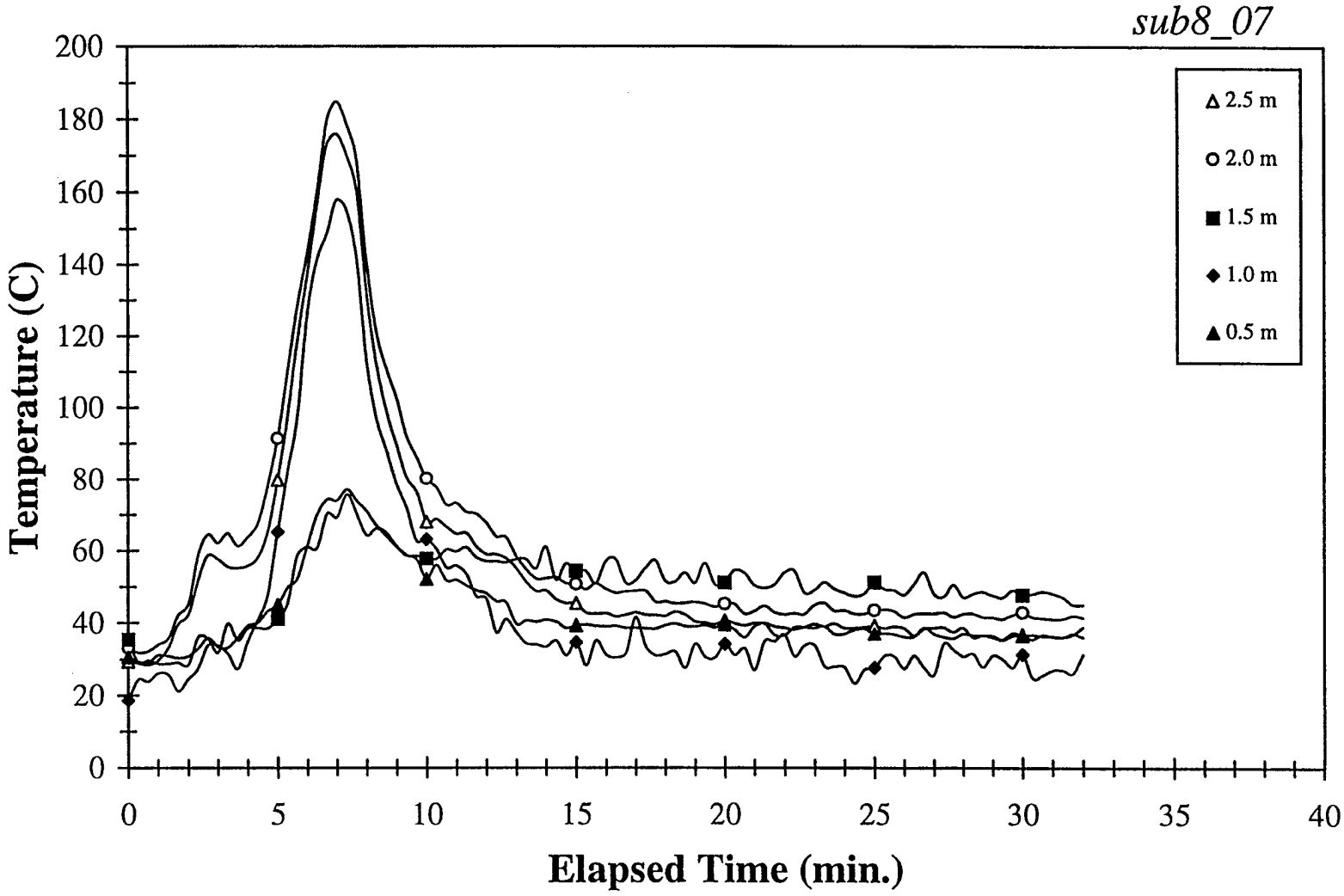

Fig. G40 – Control Room – Aft TC Tree

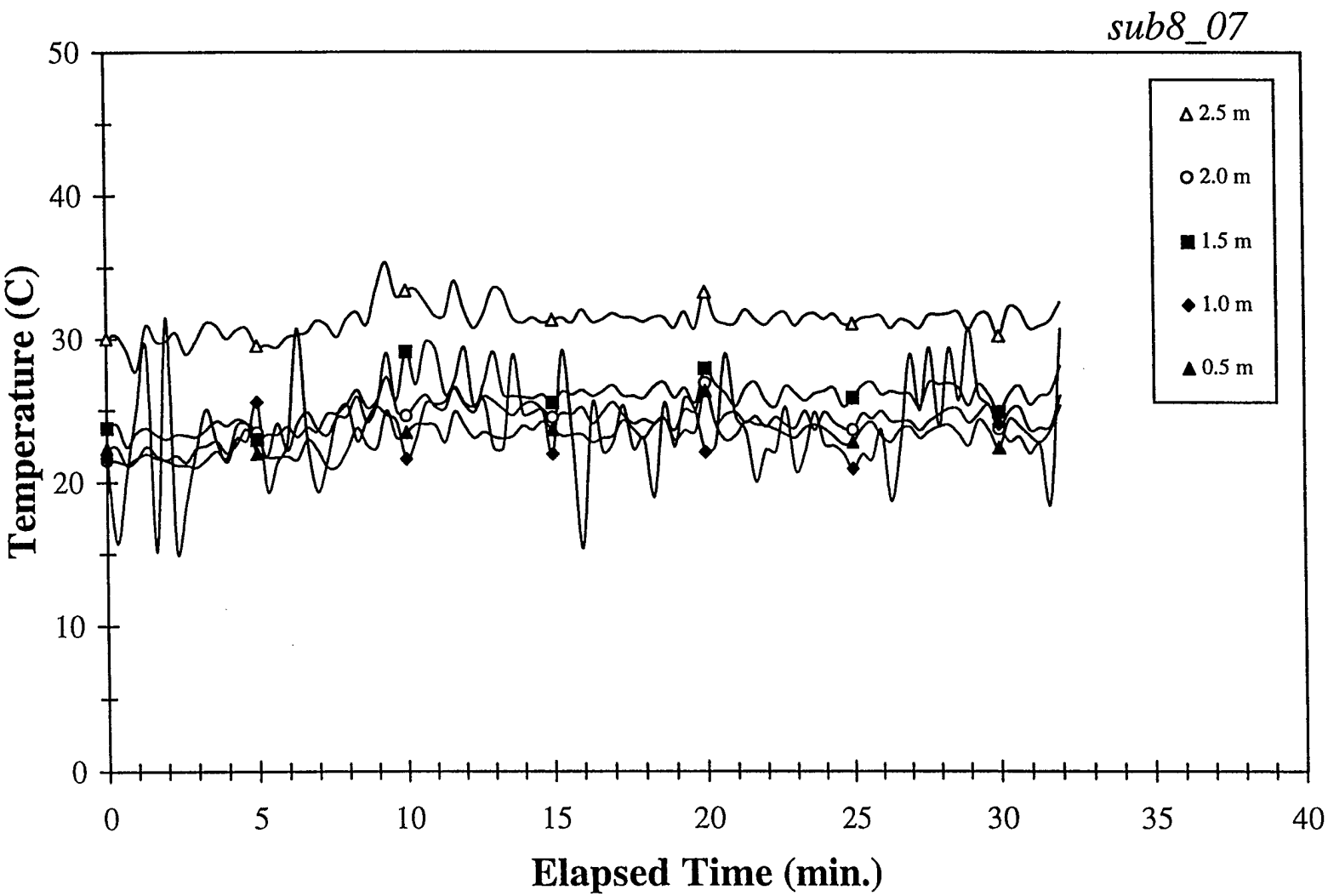

Fig. G41 – CPO/Crew Mess – Aft TC Tree

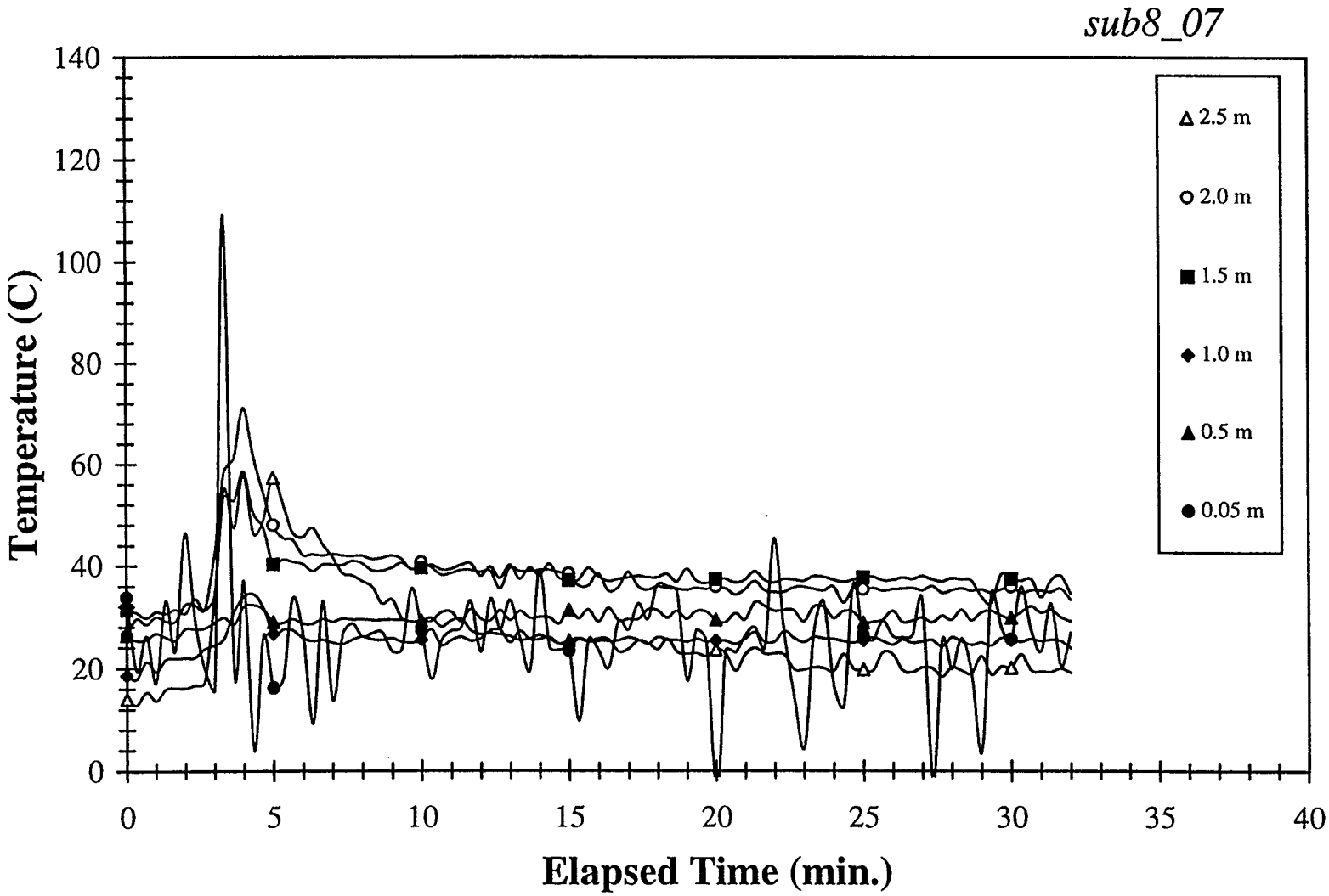

Fig. G42 – Laundry – Aft TC Tree

Appendix H

Timelines of Key Events

Test No. Sub8_01 Date: 16 June 1997
Test Description: Class A Fire in Laundry Fire Compartment

TIME	EVENT
14:54:53	Fire Ignited
14:35:10	DC Central Reports Smoke In Control Room
14:56:30	Fire Called Away over 1MC
14:57:30	Ventilation Fans Secured
14:57:40	Hose on Scene
14:58:00	"Fire Main Pressurized" over 1MC, First Portable Extinguisher Reported on Scene
14:58:58	Portable Extinguisher Going Into Fire Compartment (2nd or 3rd Extinguisher)
14:59:05	Safety Team Reports Flames Secured
15:00:25	No Visible Flames Reported by MIC to DC Central
15:01:25	"NFTI Operator Report to Man in Charge on Scene" over 1MC
15:02:10	"Fire Out" By Man in Charge to DC Central
15:02:35	"Fire is Out" over 1MC
15:03:07	"Prepare to Emergency Ventilate" over 1MC
15:05:34	Putting CO_2 on Hot Spots
15:06:30	DC Central Informed Boat at Periscope Depth (11:37)
	Induction Fan on at 4500 cfm, Induction Valve Open
	L.P. blower on at 1500 cfm, Exhaust Valve Open
15:07:21	"Commencing Emergency Ventilation" over 1MC
15:07:58	"Cooling Hot Spots with Fire Hoses on Scene" reported by MIC to DC Central
15:10:04	"No Hot Spots or Injured Personnel" reported by Man in Charge to DC Central
15:11:02	"Fire Out, No Secondary Hot Spots, No Injured Personnel" over 1MC
15:11:45	"Fire Being Cooled Down with Primary Hose, Reflash Watch on Scene" reported by MIC to DC Central
15:12:35	"Reflash Stationed with Primary Hose Team" over 1MC
15:14:20	"Preparing to Open Bridge Hatch" over 1MC
15:18:55	Smoke Not Clearing in Laundry reported by MIC to DC Central
15:21:06	"De-Pressuring Hose Number 2" reported by MIC to DC Central
15:23:06	"Securing Test" over 1MC (28:13)

Test No. Sub8_02 Date: 17 June 1997
Test Description: Class A Fire in AMR

TIME	EVENT
09:02:33	Fire Ignited
09:05:28	"Fire in Forward Compartment" over 1MC
09:06:28	Ventilation Fans Secured
	"Watchstander Report Service on Fire" over 1MC
09:07:55	Fire in Machinery Room Port by Man on Scene
09:08:20	"Fire Main Pressurized" over 1MC
09:08:50	"Fire in Machinery Room" over 1MC
09:09:50	"Fire Confirmed In Machinery Room" by MIC to DC Central
09:10:20	MIC Wants Second Hose Team Down Aft Scuttle in Crews Mess into Machinery Room
09:10:58	Applying Water on Fire
09:11:20	Second Hose From Torpedo Room (Forward) Stretched
09:12:50	"Hose Team 2 and NFTI Operator--Attack Fire From 2nd Level Scuttle" over 1MC
09:14:10	Primary Hose Team Attacking Fire, Fire Still Burning, Heavy Smoke on 3rd Level"Reported by MIC to DC Central
09:15:40	DC Central Notified Boat at Periscope Depth
09:17:30	Second Hose Team Dropping Hose Down Scuttle
09:18:10	Second Hose Team Entering Machinery Room Through Scuttle
09:18:38	"Fire Out, Cooling Hot Spots" reported by MIC to DC Central
09:19:25	"Fire is Out with Primary Hose, Prepare to Emergency Ventilate" over 1MC
09:21:18	"Back Out Hose Team Number 2 and Depressurize" over 1MC
09:22:25	"Announce 'Commence Emergency Ventilate' over 1MC" by DC Central (19:52)
09:22:49	"Commencing Emergency Ventilate" over 1MC
09:25:10	Hose teams Used 675 Gallons
	"CDR Caudle Report to DC Central & Effect Reliefs" over 1MC
	2 Personnel Out of Space (1 in OBA and 1 in SCBA)
09:36:00	NFTI Operator Has Only 5 minutes on OBA, MIC has 6 minutes on OBA
09:36:25	Secure From Test (33:52)

Test No. Sub8 03 Date: 17 June 1997
Test Description: Class A Fire in AMR and Class A Fire in Laundry Compartment

TIME	EVENT
13:08:36	Fire Ignited
13:10:32	"Watchstander Report Location of Smoke" over 1MC
13:10:48	Fire in Laundry Reported by Watchstander to DC Central
13:11:58	Ventilation Fans Secured
13:12:28	"Fire Main Pressured" over 1MC
13:13:10	Fire In Machinery Room Reported by MIC to DC Central
13:13:40	"Fire In Machinery Room, Fire Team 2 Respond To Machinery Room" over 1MC DC Central Visibility 0%
13:14:22	Water Flowing From Fire Hoses
13:14:44	MIC Reports Laundry Room Fire Being Attacked
13:18:45	"Fire In Machinery Room & Laundry Out, Prepare to Emergency Vent" over 1MC
13:19:40	Fire Spreading in Machinery Room and Losing Hose Pressure
13:21:30	"Fire in Machinery Room Has Flashed Press Hose #1" on 1MC
13:22:54	DC Central Requests Do Not Emergency Ventilate to SHADWELL Test Control Room
13:23:28	2 People Out Of Test Space
13:24:23	MIC Reports Fire In Machinery Room Out
13:26:05	Report by MIC That Fire Cannot Put Out In Machinery Room
13:29:08	MIC Reports Chief Smith w/AFFF In Laundry, Still Hazardous Machinery Room Fire
13:30:25	MIC Requests Additional Reflash Watch with OBA's to 3rd Platform
13:30:50	"Fires Out" Reported by MIC
13:31:21	"Fire Out, OBA Relief Requested to Relieve Reflash Watch in Machinery Room" over 1MC
13:32:00	"Commencing Emergency Ventilation" over 1MC (23:24)
13:33:08	Light Smoke out Exhaust Port in Sail
13:36:13	MIC Reports Smoke Clearing on Lower Level
13:36:54	MIC Requires Nozzle Man Relief in Machinery Room
13:37:53	DC Central Visibility Improving
13:40:20	DC Central Visibility Improving, Over 10%
13:43:12	DC Central Requests Securing Test
13:43:40	"Secure From Test" over 1MC (33:04)

Test No. Sub8_04 Date: 18 June 1997
Test Description: Class A&B Fire in AMR

Time	EVENT
10:29:23	Fire Ignited
10:31:57	"Watchstander Report Location of Smoke" over 1MC
10:32:20	1st OBA Ignited
10:33:40	"Fire In Machinery Room" over 1MC
10:34:40	Ventilation Fans Secured
10:35:18	Fire Main Pressured" over 1MC
10:36:10	MIC Reports Fire In Forward Machinery Room
10:37:00	"Fire Located In Machinery Room, Forward Port Corner" over 1MC
10:37:23	3 Dive Blasts "Prepare to Surface" over 1MC
10:38:50	"Prepare to Sweep Control Room" over 1MC
10:40:45	DC Central Reports Ship Ready To Surface
10:42:40	Begin Control Room Sweep (13:17)
10:42:43	"Surface Surface Surface" over 1MC
10:43:45	MIC Reports 2nd Machinery Room Fire Out with Portable extinguishers, Working on Primary Fire, H1 Opened
10:44:10	DC Central Reports Improve Visibility
10:45:10	MIC reports 2nd Fire In Machinery Space
10:45:30	"Second Fire Reported in Forward Machinery Room" over 1MC
10:47:36	Smoke Moving Up to Upper Levels Through Ladders
10:47:54	Second Fire Out, Fighting Primary" Reported by MIC to DC Central
10:48:33	MIC Reports Both Fires Out, Visibility Improving to DC Central
10:48:58	"Both Fires Out On" over 1MC
10:50:28	MIC Recommends Starting Supply Fan to DC Central
10:50:51	Supply Fan On At 6300 cfm (21:28)
10:52:35	MIC Reports Improving Visibility In Machinery Room to DC Central
10:53:15	"Crews Mess Bring AFFF to MIC in Machinery Room" over 1MC
10:54:07	"Crews Mess Bring All Available AFFF to MIC In Machinery Room" over 1MC
10:57:13	"OBA Watch Relief Without FFE to Machinery Room" over 1MC
10:59:00	"Back out Hose Number 2" over 1MC
10:59:20	NFTI Number 2 Reports Smoke Clearance in Machinery Room to DC Central
10:59:50	"Smoke Clearing In Machinery Space" over 1MC
11:00:04	NFTI Operator Number 2 Reports Visibility Approximately 10 ft
11:01:48	"Back out Hose #1" over 1MC
11:02:30	"30 minutes Since First OBA Light Off" over 1MC
11:03:45	DC Central Recommend Secure Test
11:04:00	"Secure From Test" over 1MC (34:37)

Test No. Sub8_05 Date: 18 June 1997
Test Description: Class A&B Fire in AMR

Time	EVENT
13:40:25	Fire Ignited
13:41:50	"Watchstander Investigate Source of Smoke" over 1MC
13:43:27	Watchstander Report Fire In Machinery Room To DC Central
13:43:40	"Fire In Machinery Room" over 1MC
13:44:40	Ventilation Fans Secured
13:45:12	"Fire Main Pressurized" over 1MC
13:46:20	MIC Reports Fire Port Forward Corner, Discharged AFFF and One PKP to be Discharged to DC Cental
13:46:40	"Fire In Forward Port Corner of Machinery Room" over 1MC
13:47:49	MIC Suggests to Emergency Surface to DC Central
13:48:07	"Prepare to Surface" over 1MC
13:50:26	"Prepare to Sweep Control" over 1MC
13:50:45	MIC Reports Fire Out
13:51:27	"Both Fires Are Out" over 1MC
13:52:05	MIC Requests Hose Team 2 Back out
13:53:10	DC Central Reports Ready To Surface
13:53:12	"Surface Surface Surface, L.P. blower On (12:47)
13:53:50	Supply Fan On At 6300 cfm (13:25)
13:54:50	"Supply Fan Running" over 1MC
13:55:00	Induction Fan On At 4500 cfm (14:45)
13:55:53	"Back Out Hose #1, Induction Fan Running" over 1MC
13:57:02	MIC Reports Smoke Clearing On Lower Levels
13:59:40	No Hot Spots or Injured Personnel on 2nd and 3rd Level
14:00:23	SHADWELL Test Control Room to DC Central "Open AMR L.P. blower Terminal & Close NAV Equip Room L.P. blower Terminal" - Agreed
14:02:25	MIC Reports VH-15 Open, DC Central Confirms NAV Equip Room Cleaned (22:00)
14:03:11	"Now Ventilate Machinery Room" over 1MC, MIC Reports Smoke Clearance In Machinery Room
14:05:15	Control Room Visibility Approximately 97%
14:08:35	"Secure From Test" over 1MC (28:10)

Test No. Sub8_06 Date: 19 June 1997
Test Description: Class A Fire in Laundry Fire Compartment Extending Up To Involve Wooden Wardroom Framebay Mockup

Time	EVENT
09:22:30	Fire Ignited
09:25:11	First OBA Light Off
09:25:28	"Watchstander Report Source of Smoke" over 1MC
09:26:50	Watchstander Reports Fire in Laundry to DC Central
09:27:55	Ventilation Fans Secured
09:26:55	"Fire In Laundry" over 1MC
09:28:34	"Fire Main Pressurized" over 1MC
09:29:50	"Investigate Fire in Laundry" over 1MC
09:29:50	"Prepare to Emergency Surface" over 1MC
09:30:29	"Surface Surface Surface" over 1MC
09:38:23	MIC Needs Crowbar in Laundry to DC Central
09:31:32	"Crews Mess Sends Crowbar to Laundry" over 1MC
09:30:20	"Prepare to Sweep Control Room" over 1MC
09:33:00	MIC Wants Primary Hose Team to Laundry and Second Hose Team to Report to Ward Room
09:33:14	"Primary Hose to Laundry, Second Hose Team to Ward Room" over 1MC
09:35:13	"ABT-13 Open" by MIC to DC Central
09:35:30	Opening Bridge Hatches
09:35:48	"Surface Surface Surface" over 1MC
09:35:48	Commence Control Room Sweep
09:36:06	L.P. blower on
09:36:10	Secure All Fans
09:37:20	"Fire in Laundry and in Ward Room Out" reported by MIC to DC Central
09:37:47	H1 Open, L.P. blower on (15:17)
09:38:19	"Fire in Laundry and Ward Room Out" on MIC
09:39:30	MIC Requests Supply Fan on to DC Central
09:39:32	Supply Fan on at 6300 cfm (17:02)
09:40:57	"Commence Ventilation with Supply Fan" over 1MC
09:42:07	NFTI Operator 2 Reports no Embers in Ward Room to MIC
09:43:12	"Ward Room Fire Has Been Overhauled" over 1MC
09:43:47	MIC Reports Laundry Fire Overhauled to DC Central
09:44:01	Induction Fan on (21:31)
09:44:02	"Reflash Watch to Ward Room with OBA's" over 1MC
09:49:25	"Back 2nd Hose Team Out of Ward Rom and Secure" over 1MC
09:49:00	Reflash Watch Set in Ward Room with Portable Extinguishers by MIC to DC Central
09:55:11	Secure Test (32:41)

Test No. Sub8_07 Date: 19 June 1997
Test Description: Class A Fire In Laundry Fire Compartment, Class A Fire in Laundry Fire Compartment Extending Up To Involve Wooden Wardroom Framebay Mockup, and Class A and B Fires in AMR

TIME	EVENT	
13:45:26	Fire Ignited	
13:47:34	"Watchstander Report Source of Smoke in Forward Compartment" over 1MC	
13:48:13	"Fire in Forward Comp. Lower Level" over 1MC	
13:49:13	Ventilation Fans Secured	
13:49:32	"Fire Main Pressurized" over 1MC	
13:50:15	3 Rounds of Dive Horn, "Surface Surface Surface" over 1MC	
13:50:33	MIC Reports Source of Fire in Laundry to DC Central	
13:50:35	"Fire in Laundry" over 1MC	
13:50:38	Surface Surface Surface over 1MC	
13:51:15	"Fire in Machinery Room, Forward Port Corner" over 1MC	
13:51:40	"Release Rapid Responders	
13:51:48	Prepare to Sweep Com. Room" over 1MC	
13:52:58	DCC Requests Position of ABT-13 to MIC	
13:53:40	DCC Requests Open H1	
13:54:10	MIC Reports Fire in Machinery Space Out	
13:54:27	Fire in Machinery Room Out" over 1MC	
13:54:50	"Fire in Laundry Out" over 1MC	
13:55:47	H1 Open	(10:21)
13:56:10	"Surface Surface Surface, Commence Sweep" over 1MC, L.P. blower on	(10:43)
13:56:56	MIC Reports Mach Room Fire was a Class B and Laundry Fire was a Class A	
13:57:40	Supply Fan on at 6300 cfm (12:14)	
13:58:40	Induction Fan on at 4500 cfm	(13:14)
14:00:53	"Fires Out and Reflash Watches Set" over 1MC	
14:01:30	MIC Requests EAB Personnel To Relieve Reflash Watch" over 1MC	
14:05:03	MIC Reports Smoke Clearance on 3rd Platform to DC Central	
14:05:41	"Smoke Clearing on 3rd Platform" over 1MC	
14:07:20	MIC Wants to Back Out Hose Team 1	
14:07:28	"Hose Team 1 Back Out and De-Pressurize Hose " over 1MC	
14:08:54	MIC Wants Hose Team 2 to Back Out	
14:09:00	"Back Out Hose Team 2 and De-Pressurize" over 1MC	
14:16:15	"Secure From Test"	(30:49)